The Lower White River beds in North Dakota, at least some of them, resemble portions of the beds of nearly the same age in Montana ; but the Middle White River is different in appearance in the two places.

It is evident that the later Tertiary deposits in Montana accumulated in various ways (as water-borne sediments and wind-blown dust accumulating in lakes, marshes, and streams, and as sheet-wash and flood-plain deposits, etc.), in large river valleys excavated in later Eocene times.

I have little doubt that the upper Tertiary deposits in North Dakota were also deposited in broad valleys of erosion. Much of the material of the deposits came from areas of granite and quartzite rock. In the region of the Black Hills are the only outcrops of these rocks for hundreds of miles ; this, connected with the fact that a series of remains of Oligocene deposits have been observed to extend from Dickinson to the Black Hills, suggests the probability that a river formerly flowed from the Black Hills northeastward through this region. If this be true, there should be coarse sediments as the mountains are approached, which is probably the case. Another thing, which tends to confirm the idea that these are river-valley deposits, is the fact that, scattered over the plains, there are buttes apparently as high as White Butte, but which are not capped by later Tertiary beds. However this may be, it will undoubtedly be possible to trace approximately the courses of some of these ancient rivers eastward from the Cordilleran region.

Apparently the Middle White River was deposited after considerable erosion of the Lower White River. I have not seen much evidence of erosion of the Middle White River (Oreodon) beds, previous to the deposition of the Upper White River, but the latter was evidently accumulated under more complex conditions, portions of the deposits being eroded and refilled with stream-deposits, etc. In the Little Bad-lands in one place what appears to be the channel of a river, or small stream, has been excavated in the clay, and afterward refilled with water-worn sand.

IX. A BOTANICAL SURVEY OF PRESQUE ISLE, ERIE COUNTY, PENNSYLVANIA.[1]

By Otto E. Jennings.

(Plates XXII–LI.)

Introductory.

The peninsula of Presque Isle at Erie, Pennsylvania, is in many respects one of the most interesting localities in the western part of that state. To the botanist it affords unexcelled opportunities for collecting and for field-studies, and, indeed, there is probably nowhere else about Lake Erie a locality, where undisturbed vegetation may be studied as at Presque Isle.

Detailed studies of the bird-life of Presque Isle having been made under the auspices of the Carnegie Museum,[2] it was determined that the plant-life of the peninsula should also be investigated. Accordingly the writer made a series of trips to the place, collecting and making field-studies on the following dates: May 15–17, June 9–11, and August 24–26, 1905 ; May 8–10, June 5–7, and September 20–22, 1906. The collections thus made were critically studied in the laboratory, as were also the collections in the Herbarium of the Carnegie Museum made at Presque Isle by Professor Gustave Guttenberg in 1878–1880, while connected with the Erie High School ; and the collections made on Presque Isle by Dr. John A. Shafer, September 9–11, 1900, while connected with the Carnegie Museum.

The hearty thanks of the author are here due to Dr. W. J. Holland, the Director of the Carnegie Museum, for his ready approval of the plans of the author in this work and for his editorial supervision of the manuscript ; to the United States War Department at Washington for permission to use certain early maps and charts of Presque Isle, and to

[1] Paper presented as one of the requirements for the degree of doctor of philosophy in the University of Pittsburgh.

[2] Todd, W. E. Clyde. "The Birds of Erie and Presque Isle, Erie County, Pennsylvania." Ann. Car. Mus., Vol. II, pp. 481–596, 1904. To the introduction of this article the reader is referred for a brief general description of Presque Isle and its larger vegetational features.

Mr. J. G. Sanders, of Washington, for having made tracings of these maps and charts; to Mr. George H. Fenkell, Engineer of the City Water Works of Erie, and to Mr. Andrew W. Shaw, Keeper of the Presque Isle Light, for many courtesies, which added to the success and pleasure of the work. For the lettering of the maps the author is indebted to Mr. Sidney Prentice, to whom also are due many thanks for suggestions and assistance in preparing the drawings and photographs, which, unless otherwise indicated, are the work of the author, assisted by Mrs. O. E. Jennings.

In matters pertaining to botanical nomenclature the author has endeavored to the best of his ability to keep this article thoroughly in accord with recent discoveries and advances, while at the same time the effort has been made to adhere consistently to the principle of priority as maintained in the amended Philadelphia Code of Botanical Nomenclature, published in 1907.

THE PHYSIOGRAPHIC ORIGIN OF PRESQUE ISLE.

Although the larger associations of plants, such as those of the desert, the prairie, open forests, and dense forests, are to be correlated with certain general climatic conditions, it is no less evident that the smaller associations of more restricted areas, such as societies and formations, and the sequence of formations in a succession, are to be correlated with local physiographic conditions.

It is thus evident that the best knowledge of the ecological associations of a locality is only to be obtained in connection with physiographic studies, including such factors as the composition of the soil, physical and chemical; moisture of the soil; topography; etc. Cowles[3] has been one of the first of a rapidly widening circle of ecologists in America to carry on extended studies of the vegetation of a region from the standpoint of "physiographic ecology," *i. e.*, considering the vegetation of a region as the natural expression of its physiography.

The topography and development of lake-shores has been the subject of very careful investigation,[4] especially in the case of the Great

[3] Cowles, H. C. "The Ecological Relations of the Vegetation of the Sand Dunes of Lake Michigan." *Bot. Gaz.*, 27: 95–117, 167–202, 281–308, and 361–391, February, March, April, and May, 1899.

[4] Gilbert, G. K. "Topographic Features of Lake Shores." U. S. Geol. Surv., Ann. Rpt., 5: 69–123, 1884. And Russell, I. C. "Lakes of North America," 1895.

Lakes, and from certain general principles thus ascertained the origin and growth of a peninsula such as Presque Isle is easily understood.

By far the most potent factors in determining the topography of lake-shores are waves and currents. In Lake Erie the amount of inflow and outflow is hardly to be considered as a factor in the production of currents, because of the relatively very broad expanse of the basin of the lake and the action of other more powerful factors, but investigations undertaken by the United States Weather Bureau[6] have shown that there is a system of currents, the general trend of which is east through the North Passage and thence southeast towards the shore from the vicinity of Lorain eastward. The currents must evidently be due to the action of the prevailing winds, especially the more severe storms. The larger axis of Lake Erie lies almost directly in the normal path of cyclonic storms[6] and, as the bed of the lake is comparatively shallow, the wave-action thus produced is particularly strong, resulting in pronounced currents.

There is also a considerable shifting of the waters from one end of the lake to the other, due to barometric pressures. The barometric pressure often varies an inch within the length of Lake Erie and, when this factor acts in conjunction with high winds, considerable fluctuations may occur in the height of the water. Fluctuations of as much as fifteen feet have been noted within the space of a few days at the eastern end of the lake.[7]

When waves from the west break upon the shelving beach of the southern shore of Lake Erie, there is near the shore a movement of water towards the beach, and, as the angle of incidence is oblique, there is a tendency for the wave to retreat as an undertow towards the northeast. The usual result is that there is formed close to the shore a current running northeastward, parallel to the shore. To such littoral currents we may in a general way attribute the formation of Presque Isle.

It has been found that in deep water the lateral movement due to a wave is very slight, but when approaching shore the friction on the bottom increases, so that the upper part of the wave finally topples over, forming a breaker. Much of the force of the wave is here ex-

[5] Russell, I. C. "Lakes of North America," pp. 32–33, 1895.

[6] United States Weather Bureau. "Climatic Charts of the United States. Chart No. 4, 1904."

[7] Russell, I. C. *l. c.*, p. 34.

pended, and during the impact of the water upon the bottom, as the wave topples over, the sand or gravel may be knocked and churned about to a considerable extent. From the breaker the water rushes quickly landward and then more slowly recedes, carrying the sand and gravel forward and backward, but, owing to the establishment of a certain equilibrium between the greater shoreward thrust and the combined weaker outward flow and the action of gravitation there results a more or less constant slope of the beach.

The ordinary littoral current unaided would not be strong enough to transport any considerable amount of coarser material, but in the line of the breakers there is a suspension of more or less of the coarser sand and gravel at the impact of each breaking wave, and the littoral current may thus cause a lateral displacement of the debris during its suspension in the water. In this manner there may occur a gradual drifting of shore debris along the line of the breakers, the material being replaced from the upper parts of the beach as fast as it is carried away.

From the mouth of the Vermilion River, Ohio, eastward to Dunkirk, New York, a total distance of about one hundred and sixty miles, the immediate shore of Lake Erie consists of the soft blue Devonian shale, named by Dr. Newberry the Erie Shale,[8] covered with a varying thickness of drift-clay, thus constituting an easily eroded shore-line favorable to the formation of a typical beach. In the vicinity of Cleveland, Ohio, "The mean recession of a line of prominent sea-cliffs in boulder clay, for a period of forty years, has been about six feet per annum."[9]

There is thus a large amount of beach debris annually taken into the waters of Lake Erie from this region and almost the entire shore of Lake Erie from Sandusky Bay eastward presents a typical beach of sand or gravel, strewn here and there with boulders from the drift-clay above. Such a beach under the action of suitable currents will develop the various beach structures, as barriers, terraces, bars, spits, hooks, loops, etc.

The littoral current, following the line of agitation of the surf-line, may deviate from this course in three ways. It may (*a*) cut across bays, etc., and join the surf-line again at the other side, forming a "spit," "hook," "bar," or "loop." It may (*b*) leave as a surface-

[8] Newberry, J. S. "Geological Survey of Ohio. Report I." Pp. 163–167, 1873.
[9] Russell, I. C. *l. c.*, p. 61.

current, or, (*c*) as a bottom-current, in either case depositing its load as a "terrace." Presque Isle has, evidently, been initially formed as a spit somewhere along the shore farther to the west and has been slowly shifting its position to the east. It is claimed[10] that at about 1800 A. D., a sand beach extended from the mouth of the run, one mile west of the present "head" of the peninsula, and from there the peninsula jutted out. A long narrow pond extended from the bay between the peninsula and the mainland and as late as 1840 scows were run in there from the bay for firewood. At that time the peninsula was said to be much wider at the western end than it is now.

As now constituted Presque Isle is to be regarded as mainly the joint product of four natural agencies somewhat modified in certain particulars by man: (1) A littoral spit-forming current deviating from the surf-line; (2) Conflicting currents tending to turn the spit inward, thus forming a recurved spit or hook; (3) The ridge-forming surf of great storms from north and northeast; (4) The soil-accumulating and soil-binding effect of the vegetation, aided by the drifting power of the wind.

Under the prevailing westerly winds there is a constant movement of the beach-debris towards the east, both in the littoral current, as before mentioned, and on the beach higher up. The breaking wave as it rushes obliquely up the beach carries many particles of sand and pebbles with it and, retreating obliquely in the other direction, leaves them often several inches to the east of their former position. During a moderate surf on one occasion, with the waves striking the beach at an angle, the writer observed rounded flat pebbles of about an inch in diameter moving eastward in this manner. The marked pebbles were not shifted with each wave but occasionally they would be shifted a foot or more at one time, the general average during some twenty minutes of observation being one and a half inches per wave. Under such conditions it thus appears that certain of the looser, more exposed pebbles would be transported the surprising distance of about fifteen hundred feet in twenty-four hours, provided, of course, that the pebbles remained in the same relative position on a uniform beach.

The general tendency during prevailing westerly winds is for this shifting beach-debris to be deposited at the extremity of the spit, as a

[10] Nelson, S. B. "Biographic Dictionary and Historical Reference Book of Erie County, Pa.," p. 426, 1896.

prolongation, but ordinarily there occur at irregular intervals conflicting currents due to northeast winds which carry the debris southward and tend to form a recurved spit or hook.

The most powerful agency, however, in the distribution of the beach-debris after it has reached this part of the peninsula is to be found in the surf of great northeast storms, which may pile the sand up in the form of beach-bars or ridges above and beyond the reach of the ordinary surf. In fact, it has been stated by Gilbert:[11] "The habit of the shore, including not only the maximum height of the beach-line and the height of its profile, but the dimensions of the wave-cut terrace and of other wave products, is determined by and adjusted to the great storms."[12]

The ridges and bars built up during the great northeastern storms will, of course, have a general direction parallel to the waves producing them, as will also necessarily be the case with the lagoons between the bars and the shore. As will be shown later, the damp banks of the newly formed lagoon may give rise to long lines of vegetation, along which, especially the woody species, the wind-driven beach-sand will accumulate, and, being held by sand-binding vegetation, will eventually form the great transverse ridges, which are topographically so characteristic a feature of Presque Isle.

THE HISTORICAL DEVELOPMENT AND PROBABLE AGE OF PRESQUE ISLE.

At the mouth of Sandusky Bay, towards the western end of Lake Erie, there is a peninsula, Cedar Point, the terminal portion of which very closely resembles Presque Isle in its general topography and mode of formation. The vegetation is also in many respects very similar. With respect to the physiographic development of the peninsula of Cedar Point, Professor E. L. Moseley has pointed out[13] that the succession of vegetational formations, taken in conjunction with certain historical records, furnishes a means of approximating

[11] Gilbert, G. K. *l. c.*, p. 89.

[12] The carrying power of the currents varies with the sixth power of the velocity, and the height of the waves is proportional to the square root of the distance through which they are propagated unimpeded. From this it may be seen that the effects produced upon the loose beach sand of the exposed outer extremity of the peninsula during the occasional great north or northeast storms may be very great indeed.

[13] Moseley, E. L. "Formation of Sandusky Bay and Cedar Point." *Proc. Ohio State Acad. Science*, 4: 179–238. (Thirteenth Ann. Rpt.) 1904.

the ages of various topographic structures, as well as of tracing their origin and development.

According to Moseley's classification the peninsula of Cedar Point consists of three portions: the bar, the dune-section, and the ridge-section. The dune or middle section represents a higher portion of the former mainland, now covered by sand, which reached farther out into the lake and formed a continuous coast-line with the mainland farther to the southeast. With the differential tilting of the lake basin, however, most of this portion of the mainland was inundated, leaving the dune-section more or less completely an island. A sand-bar soon connected this section with the mainland again to the southeast, thus constituting "the bar." This bar has been gradually shifted back over and upon the marsh behind it, as, especially, during the high water of 1858–1862.

This bar was evidently formed mainly by a swirl from the main lake current passing the islands, the rotation being from left to right and thus sweeping the beach-debris from the mainland at the mouth of the Huron River towards the dune-section. Eventually the sand accumulated sufficiently to begin the formation of a sand-spit at the northern extremity of the dune-section, the accumulating sand being heaped into long narrow ridges or bars by the exceptional action of high surf during great northeast storms, especially in periods of high water in the lake. The further growth of the ridges was due to the accumulation and retention of drifting sand by the vegetation growing upon them or along their sides.

The ridge-section of Cedar Point is about half a mile wide and in its middle portion are eight distinct ridges separated by long narrow depressions. These ridges are very similar indeed to those of Presque Isle. The latter, however, are considerably larger and wider, although scarcely higher.

The ridges of Cedar Point have been designated by Moseley by the numbers, 1 to 8, from the oldest to the most recent. Ridge No. 8 is about four feet in height above Lake Erie, and its vegetation consists of partially buried cottonwoods together with a few willows. The cottonwoods showed five rings of annual growth and the ridge is supposed to have been thrown up about 1897 or 1898. The jetty at the end of the peninsula, begun in 1896, probably offered an obstruction, and resulted in the accumulation of the sand forming this ridge. Cottonwoods under such conditions as obtain at Cedar Point or at

Presque Isle are seldom able to establish themselves around a lagoon, which has been separated from the lake for more than two or three years, so that the age of the cottonwoods will indicate very closely the age of the bar and its enclosed lagoon.

Ridge No. 7 at Cedar Point rises to a height of from twelve to sixteen feet above the lake, and from the age of the largest cottonwood Moseley concludes the ridge to have been formed by a great northeast storm, which occurred on September 11, 1878, or the one which occurred on August 15, 1879. Probably both contributed to the making of the ridge. Ridge No. 6 is also dominated by cottonwoods. It rises to a height of nineteen feet above the lake, and must have been formed by northeast storms during the very high water of 1858 to 1862. Among the other plants on this ridge were found several red cedars, ten feet or less in height, and, as the cottonwoods are short-lived trees, Moseley based his records of the age of the older ridges mainly upon the data furnished by the cedars, assuming from indications on the ridge-section, on the bar-section, and on the Marblehead spit, that the ridges were nearly or quite forty years old before cedars started to grow upon them.

Following these methods Moseley calculates the approximate dates of formation of the various older ridges as follows: Ridge No. 5, A. D. 1724; Ridge No. 4, A. D. 1684; Ridge No. 3, A. D. 1594; Ridge No. 2, A. D. 1504 (this ridge showing a cedar stump cut probably sixty-five years ago at an age of about two hundred and ninety-seven years); Ridge No. 1, A. D. 1429.

Following much the same methods for Presque Isle as did Moseley for Cedar Point, the writer found that there is considerable similarity in the probable ages of certain corresponding ridges on the two peninsulas. The probability is that most of the great northeast storms which affected Cedar Point also affected Presque Isle.

The bar between lagoon "Aa" and Lake Erie (see map of Presque Isle, Plate XXII, 218) was evidently formed about 1902–3, some of the little cottonwoods around the banks of the lagoon being in their fourth year in 1906. This structure is not shown on the Lake Survey Chart of Erie Harbor and Presque Isle, as issued in 1903.

Between "Aa" and "C," on the banks of "C," are cottonwoods which were three inches in maximum diameter in 1906. The lagoon "C" was thus likely cut off from the lake in 1894 or 1895. Between "C" and "D," along the shores of the latter, are cottonwoods with

a maximum diameter of three and a half inches, so that "D" and its ridge are little, if indeed any, older than "C" and its ridge.

Around "E" and "F" the largest of the cottonwoods are almost ten inches in diameter and we must probably regard them as having started in 1882 or 1883. Probably the bar was thrown up by the great storm of 1882 mentioned by Moseley.[14]

Immediately to the east of the Presque Isle Light, which was established in 1872, there branches off from the beginning of the "Long Ridge" a well defined ridge, which is now being washed away by the lake about half a mile from the Light House Jetty. This ridge reaches a height of about twenty-one feet above the lake at this point and from there continues for about a mile towards the Fog Whistle, becoming lower and broken towards the east. One of the largest of the cottonwoods which form the backbone of the ridge has been undermined by the lake and toppled over. Where it had been cut to free the Light House telephone wire it had twenty-six annual rings of growth. This ridge evidently was finished, as far as the work of the waves was concerned, about 1878; it was formed, perhaps, by the same storm which formed Ridge No. 5 at Cedar Point (see Plate XXXVII).

"Long Ridge" on Presque Isle begins a short distance west of the Presque Isle Light, and runs nearly due east for almost two miles. Near its middle it has a maximum width of about nine hundred feet, narrowing towards each end. At the eastern extremity it bends sharply to the south and continues somewhat brokenly for another mile. At its western end the ridge can be seen to be made up of three distinct components, which, however, immediately lose their identity towards the east, although the alignment of the cottonwoods would indicate formerly separate ridges. Long Ridge has an estimated height of twenty or more feet above the lake, and rises often to a height of seven and a half or eight feet above the neighboring sand-plain. It is everywhere covered with cottonwoods, and much red cedar and white pine at the western end. The largest of the cottonwoods, on the north side of the ridge, measured twenty-two inches in diameter, while towards the south side of the ridge the cottonwoods are older and appear to be dying out. This inner (south) side of the ridge, next to Yellow Bass Pond, has red cedars up to eight inches in maximum diameter, while, in the depression near the union of Long Ridge with the outer ridge, there is a clump of white pines reaching a maximum diameter of fourteen inches.

[14] Moseley, E. L. *l. c.*, p. 182.

A sketch of Presque Isle made by J. S. Brown, September 30, 1837, shows, (Fig. 3) the eastern boundary of the peninsula to have been situated at the present position of the eastern part of Long Ridge, including the part running south towards the old U. S. Pier. A survey made in 1817 and 1818 by Lieutenant H. W. Bayfield (Fig. 2) indicated roughly a line of dunes around the northern and northeastern

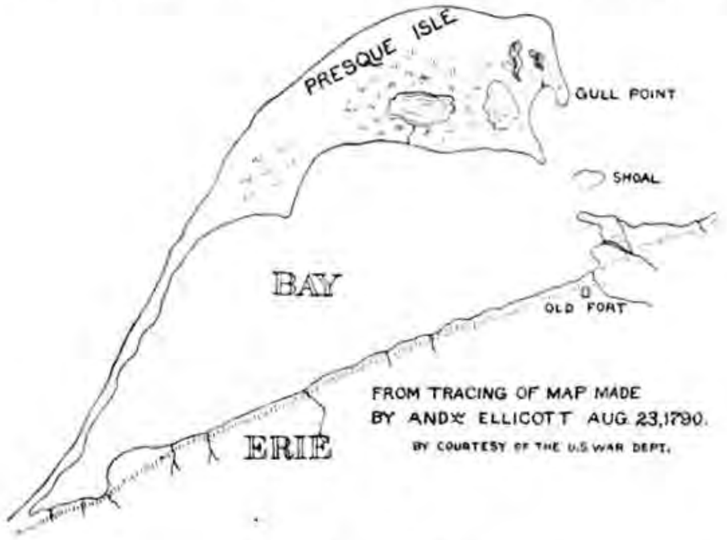


FIG. 1. Presque Isle, 1790.

shores of the peninsula, the shore-line (approximately the present inner border of Long Ridge) terminating in a small sand-spit which evidently later developed into the low ridge between Yellow Bass Pond and Niagara Pond.

Low water prevailed in Lake Erie in 1817 and 1818, but 1838 marked the climax of a period of very high water (575.11 feet above sea-level[15]) the mean water level then being 4½ feet higher than in 1808.[16] The survey of 1837 marks the sand as accumulating all along

[15] "Appendix EEE. Ann. Report Chief of Engineers, U. S. War Dept. Survey of Northern and Northwestern Lakes." 1905 : 2782.

[16] Nelson, S. B. *l. c.*, 1896. Leaving out of account an annual oscillation of about one foot in the mean water-level of Lake Erie, there have been periods of high water-level in 1812–1813, 1838, and 1858; and periods of low water in 1808, 1818, 1834, and 1895.

the eastern third of the lake shore of the peninsula so that it may be assumed that at least the interior part of Long Ridge was permanently established during the period of high water of 1838, and that the northern part was formed considerably later, probably during the high water of 1858 to 1862. A survey of the peninsula, made by John de La Camp in 1866, shows the outline of the ridge practically the same as at present, considerable sandy plain having accumulated along the western half, but towards the east it is separated from the lake by

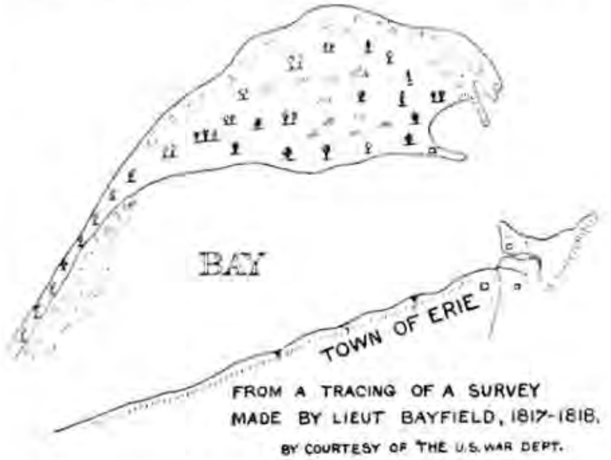


FIG. 2. Presque Isle, 1818.

merely a narrow beach. A projecting recurved spit at the point where the ridge turns abruptly to the south is evidently to be recognized to-day in the low narrow ridge which nearly divides the marsh "B." At this place are cottonwoods sixteen inches or more in diameter, thus indicating an age of at least thirty years.

The oldest of the three components of Long Ridge projects considerably to the west of Cranberry Pond and was somewhat eroded by the lake prior to the erection of the Light House Jetty. This ridge is covered by an almost pure white pine forest, the oldest of the trees having reached a diameter of seventeen to eighteen inches, breast high. This would indicate their age to be from one hundred and forty to one hundred and fifty years, and, allowing forty years for the starting of the pines, as will be explained shortly, the age of this part of the ridge

would thus be about one hundred and eighty-five years, and would be thus correlated with Ridge No. 5 at Cedar Point.

The ridge formed at this time may have been the basis for the present dividing strip between Yellow Bass and Ridge Ponds, although sand did not accumulate sufficiently to form a high ridge. There are white pines here indicating a considerably greater age for this strip than is indicated by the vegetation on the narrowing part of the ridge immediately to the north of Yellow Bass Pond.

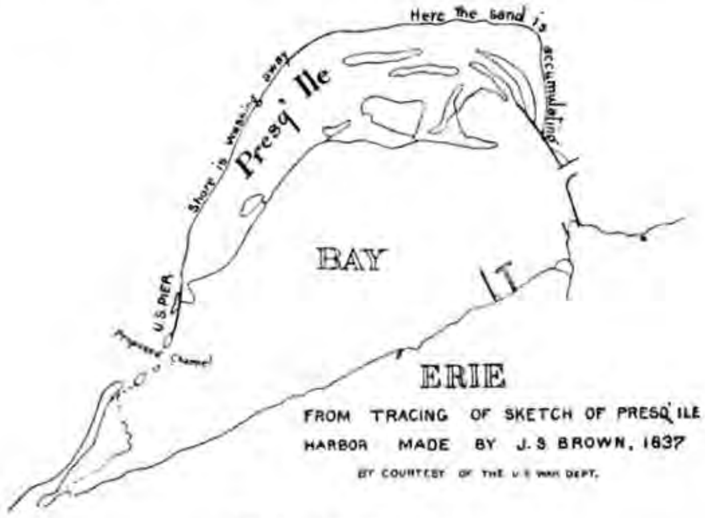


FIG. 3. Presque Isle, 1837.

According to the above considerations the younger portion, at least, of Long Ridge is to be regarded as the counterpart of Ridge No. 6 on Cedar Point. In this connection, however, it may be noted that the latter ridge consists of two more or less distinct components and it may be possible that this ridge, like Long Ridge at Presque Isle, may have been partially the product of storms during the period of high water in 1838.

Between Ridge and Cranberry Ponds there is a rather broken sand ridge showing some recent dune-formation towards its eastern end. The vegetation was evidently considerably disturbed during the building of the Board Walk, both by fire and ax, but towards the west there is considerable white pine forest mixed with black cherry and

some young black oak. The largest of the pines are now losing their lower limbs and have a maximum diameter, breast high, of nearly twenty inches, thus indicating a probable age of about two hundred and twenty years for this part of the peninsula and correlating it with Ridge No. 4 at Cedar Point.

Between Cranberry and Long Ponds there is a large ridge (IV), which, beginning near Jetty No. 2, runs slightly north of east for about a mile and a quarter, widening towards the east to about eighty rods. This ridge, at least towards the eastern end, is composed of three distinct components, the identity of the individual components

FIG. 4. Presque Isle, 1866.

having been largely obscured by the drifting of the sand and the formation of numerous dunes. The whole ridge is now covered by a dense forest consisting of black oak, white pine, cottonwood, black cherry, white ash, etc. Between Graveyard Pond (L) and Big Pond (N) there stands a cottonwood five feet and seven inches in diameter, breast high, and, comparing this with the fallen cottonwood one hundred and eleven inches in circumference which Moseley found to be about one hundred and fifty years old, the age of this tree may be estimated at approximately two hundred and seventy years. From its position and the mode of the formation of the peninsula there can be

little doubt that the land between Graveyard (L) and Big Ponds is of considerably later formation than is the ridge.

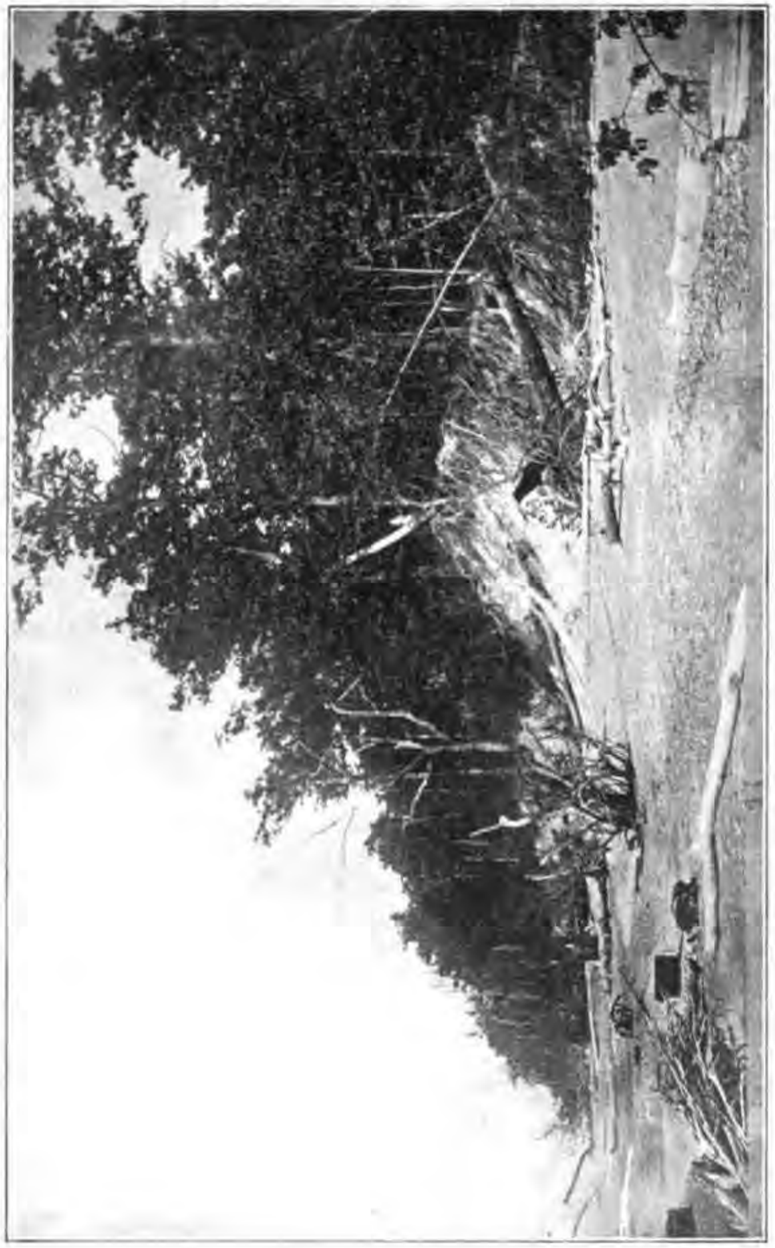
Moseley found that a ridge must have been formed "nearly or quite forty years before cedars started to grow on it." On Presque Isle the sand-plain, which had accumulated outside of the western end of Long Ridge immediately prior to the survey of 1866, now supports red cedars up to two inches in diameter and at least fifteen years old. Little plants of this species from four to five years old have in several instances been found under cottonwoods having a diameter of eleven or twelve inches, and thus it appears that on Presque Isle also cedars may become established somewhere between thirty-five and forty years after the formation of the soil. White pines appear with cottonwoods but very slightly older than those under which the first cedars may appear, and they evidently may become established on soil not more than forty years old.

The dense group of white pines at the edge of the western end of Long Ridge (see Plate XXIV) occupies ground formed probably at about the same time as the older portion of the ridge, and which was not particularly disturbed during the initiation of the younger portion of the ridge. The largest of these pines are about fourteen inches in diameter, but, having grown in an open stand, are low and bushy and are probably not more than thirty-five years old,[17] so that their age corresponds quite well with the estimated age of this portion of the peninsula.

On the ridge between Cranberry and Long Ponds the dominant tree in the forest is the black oak. The white pines, mainly confined to the northern (older) side of the ridge, have mostly reached old age and are dying out, many of them having reached a diameter of twenty-six to thirty inches. One old pine was noted near Cranberry Pond with a diameter, breast high, of thirty-eight inches. Taking into consideration the porous sandy soil, the conditions of open stand prevailing during the early years of the forest, and the uniform climatic conditions, it appears probable that the trees are from two hundred and sixty to two hundred and seventy years old, and this, in turn, would indicate for the younger part of the ridge an age of about three hundred years, correlating it with Ridge No. 3, at Cedar Point, which is also apparently a compound ridge. The composition of the forest is in

[17] Spalding, V. M., and Fernow, B. E. "The White Pine." U. S. Dept. Agr., Division of Forestry, Bull. 22: 29. 1899.

Pinus Strobus invading *Panicum-Artemisia* formation near the west end of Long Ridge. Dead *Myrica* and *Alnus* under *Pinus*, and *Juniperus* under shelter of cottonwoods to the left. Photographed May 8, 1906.



Near Jetty No. 3, showing the truncated end of Ridge 6 and the *Quercus velutina* forest formation being undermined.
Photographed June 10, 1906.

both cases a vigorous black oak forest with white pines, which have reached old age.

The southern side of this ridge next to Long Pond is covered with an almost pure black oak forest, many of the trees being twenty-four inches or more in diameter, although relatively low and bushy. This part of the ridge likely corresponds to Ridge No. 2, at Cedar Point, dating from approximately 1500 A. D.

The two narrow ridges between Long Pond and Big Chimney Pond are each about one and one half miles long, about one eighth of a mile apart, and run parallel to each other almost due east and west. These ridges are covered by a mature black oak forest, some of the trees having reached old age and fallen. Trees were noted with a diameter of at least forty-six inches. The shallow trough between the ridges has also a few large elms. The youngest of these ridges may correspond to the oldest ridge on Cedar Point, which Moseley notes as having "many large black oak, American elm and other trees." A rough estimate would place the age of this ridge at not far from five hundred years and the age of the oldest ridge at about fifty years more. The sandy soil is covered with about two inches of humus and there are a few clumps of hemlock trees up to five inches in diameter.

The land surrounding the Chimney Ponds is probably still older and it is not improbable that it once extended farther to the west like that portion of the peninsula immediately to the northeast. The younger ridges on the peninsula curve to the southwest, in conformity with the shore-line as the lake is approached, the middle and the eastern portions of the ridges being comparatively straight. The two ridges between Long Pond and Big Chimney Pond, however, have been washed away by the lake, their cross-sections now standing out in bold relief along the lake front. (See Plates XXV and XXXIII.) It is known that prior to the erection of the jetties this part of the peninsula was being rapidly washed away. It is stated[18] that a chart dated 1819, as compared with a map of 1878, shows a retrogression of some 1,500 feet in about three miles of the shore line of the neck of the peninsula, but that from 1865 to 1895 the shore line had been comparatively stationary. Reconstructing the curved ends of the ridges it is seen that the land now surrounding the Chimney Ponds may have extended at least half a mile out into the lake to the west. This, together with the known former attachment of the peninsula

[18] Nelson, S. B. *l. c.*, p. 417.

to the mainland farther to the southwest, would indicate a gradual shifting of the whole peninsula along the coast to the northeast. The circular Chimney Ponds have thus evidently been derived from bodies of water, like those in the vicinity of Misery Bay, created by the wearing away of the main body of the peninsula to the west, and the subsequent piling up around them of sand by the wind. The present indications are that, unless the eroding and land-building forces are kept in check by man, history will repeat itself, and that in perhaps another six hundred years, the present wider portion of the peninsula will have been washed away to form new land farther to the east, and Misery Bay and Horse Shoe Pond will have been transformed into counterparts of the present Chimney Ponds, with the main body of the peninsula stretching away to the northeast of them.

The forest covering in the vicinity of the Chimney Ponds is indicative of considerable age, as it consists of large white elms, white ashes, black oaks, cucumber trees, sassafras trees, etc., and between V and S there is considerable hemlock, one tree being fourteen inches in diameter. The sandy soil is covered with humus, in places more than three inches deep. This portion of the peninsula is surely not less than six hundred years old.

That portion of Presque Isle between the Chimney Ponds and the "Head," as the junction of the peninsula with the mainland is called, has been changed very greatly from time to time within the last century. "The neck or west side in 1812 was two or three hundred feet in width,"[19] and "it is said that in 1821 the peninsula was covered with timber from the mainland, at the head, to its southeastern point."[20] During the winter of 1828–1829 the lake broke through the narrow portion near the Head, but the Government promptly closed the breach. During the winter of 1832–1833, however, another breach occurred at the same point and this widened each year till in 1835 it was nearly a mile wide. From 1836–1839 about 3,500 feet of crib-breakwater was constructed as a protection to a proposed harbor entrance at this point, but the work was finally discontinued. In 1831 vessels drawing 7½ feet of water passed through the opening. In 1844 the gap was 3,000 feet wide and some crib-work was erected. In 1853–1856 brush and stone were used, and in 1864 the gap was reported closed by the drifting sand, although exceptionally heavy seas

[19] Sanford, L. G. "History of Erie County, Pa.," p. 250, 1894.

[20] Nelson, S. B. *l. c.*, p. 415.

still broke over into the bay. During a gale in 1874 a breach occurred, but this was promptly closed and bulk-head protections built.

During the winter of 1881–1882, in 1892–1893, and again in 1905–1906, the waves have washed over the the neck but no real breach has occurred. During 1905–1906, however, there was considerable erosion of the neck, especially behind the old pile-protection (see Map, Plate XXII). In places the beach receded at least thirty feet.

The shoaling of the bay inside the neck is progressing quite rapidly and, although the outer shore may wash away, it is probable that the neck of the peninsula will be simply shifted to the east instead of being entirely swept away. It has been stated that this section of the peninsula is increasing in mass below the water's edge, although the part above the water remains about the same, the distance between the twelve and fifteen feet depth contours, outside and inside being, in 1878, about double what it was in 1839.[21]

From the above considerations it is to be seen that the main portion of the neck of the peninsula is of approximately the same age as is much of the sand-plain to the northeast of the Long Ridge and, as will be shown later, its vegetation for this reason is also very similar to that of the sand-plain.

THE ECOLOGICAL STRUCTURE AND DEVELOPMENT OF THE VEGETATION OF PRESQUE ISLE.

General Considerations.

All plants are intimately related to more or less definite conditions of environment. These conditions are not always plainly evident, but each species exists within an environment characterized by definite biological and physical features.

In nature any given area always presents more or less constant and definite conditions of environment. Such local conditions will necessarily correspond more nearly to the environment required by some species than by others, and thus there will arise in the vegetation as a whole a grouping and localization of certain species.

The unit of vegetation is the *formation*. Plants are everywhere found associated; their association being the joint result of reproduction and the conditions of environment. To quote Clements:[22] "Association in its largest expression, vegetation, is essentially

[21] Nelson, S. B. *l. c.*, p. 417.

[22] Clements, F. E. "Research Methods in Ecology," p. 202, 1905.

heterogeneous, while in those areas which possess physical or biological definiteness, habitats, and vegetation centers, it is relatively homogeneous. This fundamental peculiarity has given us the concept of the formation, an area of vegetation, or a particular association, which is homogeneous within itself, and at the same time essentially different from contiguous areas, though falling into a phylogenetic series with some and a biological series with others. From its nature, the plant-formation is to be considered the logical unit of vegetation, though it is not, of course, the simplest example of association."

In newly formed areas of soil, no formation is likely to be permanent for any considerable length of time, for there will be changes in the environment, which will render the area less suitable to the plants occupying it than to certain other plants; or, if not really rendered unsuitable for the former, the conditions may become such that other plants may occupy the area and crowd them out by *competition*. Certain recent investigations[23] have shown that certain highly toxic secretions may be given off by many species of plants, these toxic secretions being poisonous in each case to different species to a different extent.

By *succession* the ecologist refers to the successive appearance and replacement of different formations in a given area. In such a process *invasion* is followed by a *reaction* upon the habitat. This reaction may result in the replacement of one formation by another representing a later *stage* in the succession. A *normal succession* begins with a *habitat* bare of plants (*nudation*) and ends with the more or less permanent occupation of the habitat (*stabilization*) by a formation designated as the *climax-formation* of the succession. *Normal successions* begin with new soils in *primary successions*, or with *denuded* soils in *secondary successions*. In a primary succession with a new soil the conditions are evidently not suitable for a luxuriant vegetation; usually such successions consist of many stages and reach stabilization very slowly as compared with a secondary succession.[24]

In the discussion of the structure of the vegetation of a given area,

[23] Schreiner, Oswald, and Reed, Howard S. "Some Factors Influencing Soil Fertility." U. S. Dept. Agr., Bureau Soils, Bull. 40: 1–40. 1907. And Livingston, B. E. "Further Studies on the Properties of Unproductive Soils." U. S. Dept. Agr., Bureau of Soils, Bull. 36: 1–71. 1907.

[24] For a further elucidation of the ecological terms used in this article the reader is referred to Clements, F. E. "Research Methods in Ecology," Lincoln, Nebraska, 1905.

obviously the most logical method of procedure is to trace the development from the initial formation, through the successive stages to the climax-formation. By this "developmental method" the structure and the correlations of the individual associations, of whatever rank, and the continuity of the succession, as a whole, can be discussed side by side and in a logical and natural manner. Where, however, but few stages of the succession are in evidence the treatment of the vegetational associations from the standpoint of habitat is, of course, much simpler; it may be difficult or even impossible to ascertain the whole succession.

Presque Isle offers exceptional opportunities for a developmental study of the vegetation. In the course of not more than five miles there is a continuous series of formations representing stages in several different successions, the climax-stages having been reached in a couple of the successions, at least in those where the habitat represents an age of between five and six hundreds of years. For these reasons it has been deemed best to follow the developmental method in the discussion of the ecological structure of the vegetation.

Ecology, as at present understood, is largely a development of the last decade. Warming's ecological plant geography[25] was the first successful systematic classification of the ecological plant-formations of the world. His classification was based mainly upon the watery content of the soil, the "Societies" being either hydrophytic, mesophytic, xerophytic, or halophytic. Schimper in his great work[26] went a step farther and pointed out that halophytes are essentially xerophytes and that ecological associations are to be properly classified, not according to the physical watery content of the soil, but according to the physiological availability of this water for plants.

Following these classifications many workers have made detailed studies of generally more or less localized areas. Among these workers Cowles has recognized the importance of the developmental method of classification based upon physiography and has followed out this idea in his work on the sand-dunes of Lake Michigan[27] and on the

[25] Warming, E. "Plantesamfund," Copenhagen, 1895. (Knoblauch's German translation, Berlin, 1896.)

[26] Schimper, A. F. W. "Pflanzengeographie auf physiologischer Grundlage," Jena, 1898. (English translation by Fisher, Groom and Balfour, Oxford, 1903.)

[27] Cowles, H. C. "The Ecological Relations of the Vegetation of the Sand Dunes of Lake Michigan." *Bot. Gaz.*, 27: 95–117, 167–202, 281–303 and 361–391, February, March, April and May, 1899.

physiographic ecology of Chicago and vicinity.[28] More recently Clements has brought forward the idea that the ecological conditions of the habitat can be instrumentally determined, and the formation thus be designated as a definite structure.[29]

In his studies on Presque Isle the writer did not use instrumental methods, neither the time nor the instruments for such work being available. However, a season's residence on Presque Isle, following out the instrumental methods as proposed by Clements, would form the basis for a very valuable ecological contribution and it is hoped that sometime such a study may be carried on at this place. Nevertheless the ecological conditions obtaining in the various habitats on Presque Isle are so profoundly different, and these differences are so plainly apparent, the successions are so rapid, so condensed, and, at the same time, present so complete a series of stages, practically free from the destructive effects of civilization, that there seemed abundant reasons for a survey such as has been made. Such a survey, although perhaps more properly termed a reconnaissance, must, nevertheless, precede a more exact and detailed investigation, or, in the absence of further work in the near future, will stand as a valuable record of the present larger ecological structure.

Taking up now the structure of the formation, there are to be distinguished in the formation, at all times, one or more dominant species termed the *facies*. Associated with each facies are usually other prominent species, the whole group constituting a *consocies*. Areas, the appearance of which changes from one season to another, being dominated by principal species other than the facies, are termed *societies*, and the different seasonal periods *aspects*. The aggregation of parent and offspring constitutes a group termed the *family*, and the grouping of families forms a *community*.

No attempt has been made in the present contribution to use a Latin nomenclature for ecological structures. The successions have been designated by their important formations, and the formations and their minor structures by their facies or principal species respectively.

There has been, and still is, considerable confusion in ecological nomenclature, different authors having adopted the same term for

[28] Cowles, H. C. "The Physiographic Ecology of Chicago and Vicinity." *Bot. Gaz.*, 31 : 73-108, 145-182, February and March, 1901.

[29] Clements, F. E. *l. c.*

different structures, or different names for the same structures. As to synonymous terms, in recent ecological literature, *series* has often been used for *succession*, as herein defined, *society* for *formation*, and *association* for *consocies*.

Some ecologists will, perhaps, take exception to the rank of formation which has been herein accorded certain vegetational structures, especially in the Lagoon Succession, but the corresponding habitats appear, even without instrumental determination, to be so clearly distinct and their plant-life so plainly a definite and correlated structure as to merit the rank of formation.

THE BEACH-SAND PLAIN-HEATH-FOREST SUCCESSION.

A comparatively large part of the land area of Presque Isle is to be referred to this succession. It includes all of the more northern and lakeward portion of the peninsula, commencing a short distance northwest of the Key Post (see map) and extending west and southwest. This succession resembles very closely in many respects the Beach-sand Plain-Thicket-Forest Succession adjoining it immediately on the south and southeast, and probably should be regarded as a part of the same succession, which has a more xerophytic habitat, being exposed to the full force of the more violent and colder prevailing winds from the west and northwest, and on this account is invaded by certain formations from the Northern Coniferous Forest Center, of which more will be said later.

The Beach.

As stated in the discussion of the physiographic origin and development of the peninsula, the shore-line at the eastern end of the peninsula, within the area embraced in the succession under consideration, grows outward either by the direct accumulation of detritus upon the beach or by the formation of sandbars, behind which the shallow lagoons are often quickly filled with wind-driven sand. In either case the result is a wide stretch of beach, the sand of which when dry is readily blown about by the wind. This beach constitutes the same xerophytic structure so common along the shores of all the Great Lakes. The beach along the shores of Lake Michigan, so thoroughly studied by Cowles,[30] is practically duplicated here on Presque Isle, and, following Cowles' classification, there may be distinguished two habitats in the beach proper: the *Lower Beach* and the *Drift-Beach*.

[30] Cowles, H. C. *l. c.* *Bot. Gaz.*, 27 : 114-117, February, 1899.

The Lower Beach. — The *Chlamydomonas* Formation.

The lower beach extends from the ordinary shore-line back to the average highest point reached by the waves of the ordinary summer storms. At Presque Isle it occurs quite uniformly around the entire lake shore and much of the bay-shore. Essentially equivalent to this lower beach is MacMillan's "front strand,"[31] Schimper's "foreshore"[32] and Cowles's "lower beach."[33]

At Presque Isle the lower beach is practically devoid of all plant-life of a permanent nature. Living fragments of *Vallisneria* and *Potamogeton* were often found half buried in the sand, and on one occasion, a rhizome of *Castalia* with living shoots, but none of these plants ever become established. During continued damp weather without high waves a motile single-celled alga, *Chlamydomonas* sp., occasionally appeared in the damp sand, causing a distinct green coloration. The same thing was observed by the writer in 1905 on the lower beach of Cedar Point, Ohio,[34] and was found also by Cowles[33] on the lower beach of Lake Michigan. As Cowles points out, the algæ being motile, can move about freely in the capillary water of the wet sand and it appears that they are really to be considered as migrants from the waters of the lake rather than as inhabitants of the beach.

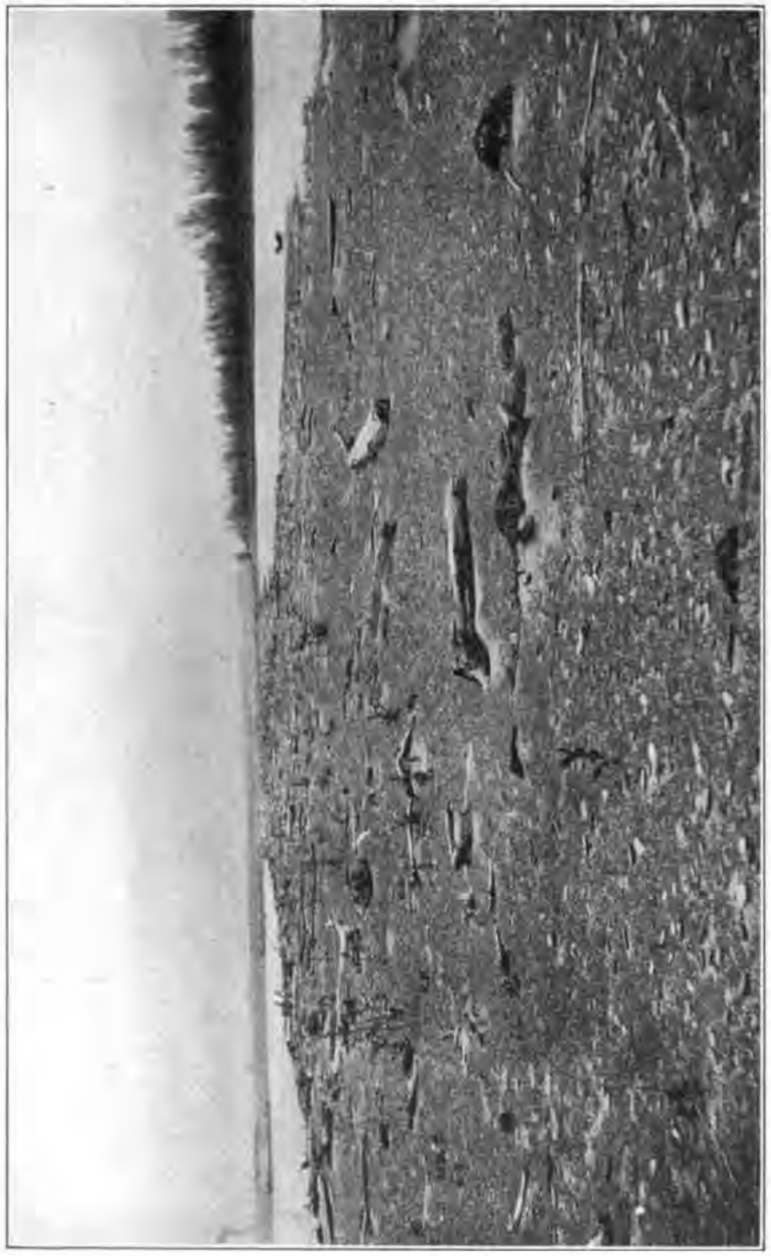
The lower beach, as a habitat, offers very severe conditions for plant-life. When washed by the waves the habitat is, of course, truly hydrophytic, but when lying exposed to the sun in clear quiet weather, the sand, at least on the surface, becomes very dry and hot, extremely xerophytic, and these extreme conditions, taken together with the mechanical violence of the waves and the very unstable character of the soil, washed about by the waves when inundated, or in quiet weather becoming dry and being blown about by the wind, make establishment impossible for any of the plants of the region, aside from the alga mentioned.

[31] MacMillan, Conway. "Minnesota Botanical Studies — Observations on the Distribution of Plants along Shore of Lake of the Woods." Geol. & Nat. Hist. Survey Minn., Bull. 9: 969. 1897.

[32] Schimper, A. F. W. *l. c.*, p. 180.

[33] Cowles, H. C. *l. c. Bot. Gaz.*, 27: 113–115, February, 1899.

[34] Jennings, O. E. "An Ecological Classification of the Vegetation of Cedar Point." *Ohio Naturalist*, 8: 291–340, April, 1908.



Newly-formed bar between Aa and Lake Erie, looking south. This is now drift beach habitat, with *Cakile-Xanthium* formation, but the *Populus Salix* formation is in evidence and a prominent sand-ridge may eventually form here. Photo. May 10, 1906.

The Drift-Beach. — *The Cakile-Xanthium* Formation.

The drift-beach (see Plate XXVI) extends from the upper limit of the lower beach, *i. e.*, the upper limit of the waves of summer storms, to the upper limit of the waves of winter storms. It thus comprises a zone immediately above the lower beach and differing from it in that it is not exposed to the mechanical violence of the surf during the growing season. Like the lower beach it is composed of loose, clean sand, but it is marked by a considerable accumulation of driftwood — whence its designation here as the *drift-beach*. This habitat is well developed at the eastern end of the peninsula and is quite well shown along the northern shore, except at the western end near the Head, where the shore is receding and the lower beach extends back to the base of a low vertical sand-cliff.

This drift-beach is essentially synonymous with MacMillan's "*mid-strand*,"[35] Schimper's "*mid-shore*,"[36] Cowles's "*middle beach*"[37] and Ganong's "*new beach*."[38]

The drift-beach, at least in its surface layers, constitutes an extremely xerophytic habitat. The loose white sand is exposed to the full force of wind and sun and the surface at times becomes very dry and hot, but as quickly loses its heat when insolation ceases. The water-table is but a short distance below the surface and damp sand is always to be found by digging down a few inches. If a plant can survive until its roots get down a few inches, there need be no lack of water from that source, but it seems probable that most of the plants whose disseminules may reach this habitat are unable to exist until their roots have reached the damp sand below. Following Clements this habitat may be termed *dissophytic*, being xerophytic above the surface layers of sand and mesophytic or even hydrophytic below.

The drift-beach is occupied by a formation, which from its composition will be termed the *Cakile-Xanthium* Formation. The habitat being exposed to the mechanical violence of the surf during the winter, the formation consists entirely of annuals, and in response to the dissophytic conditions the plants are xerophytic, at least in their aerial portions, most of them being more or less succulent.

[35] MacMillan, Conway. *l. c.*, pp. 969–973.
[36] Schimper, A. F. W. *l. c.*, p. 180.
[37] Cowles, H. C. *l. c.*, pp. 115–117.
[38] Ganong, W. F. "The Nascent Forest of the Miscou Beach Plain," *Bot. Gaz.*, 42: 85–87. August, 1906.

At Presque Isle this formation is characterized by *Cakile edentula* and *Xanthium commune*, together with the minor species: *Euphorbia polygonifolia*, *Strophostyles helvola* and *Cenchrus carolinianus*. The plants are scattered along here and there, in the line of driftwood, there being no particular localization of species, except that the *Xanthium* and *Strophostyles* occur more abundantly in the sheltered places, or in places where the driftwood is more abundant. This, in *Xanthium* at least, is probably due to the character of the disseminule, the burs of *Xanthium* in exposed places being liable to washing away by the waves, or blowing away by the wind. The most efficient method of dissemination in this habitat is a combination of wind and wave, the floating disseminules being cast upon the beach among the driftwood and there left buried in the sand, ready to grow the next season.

Along the drift-beach at Cedar Point, Sandusky, the habitat is characterized by *Cakile*, *Xanthium* and *Polanisia graveolens*, the last named being more abundant along the lake-beach while the *Xanthium* is more partial to the more protected bay-beach. Along Lake Michigan Cowles found the habitat characterized by *Cakile*, *Corispermum hyssopifolium* and *Euphorbia polygonifolia*, the first named species being generally the most prominent. He mentions *Strophostyles helvola* as an inhabitant of the narrow beach at the base of sea-cliffs, but it has "not been seen as yet on the beaches of the dune district."[39] Ganong finds *Salsola Kali*, *Cakile*, *Mertensia maritima* and a few other species on the drift-beach at Miscou Island, New Brunswick, *Cakile* being second in abundance to *Salsola* "though but scarce."[40]

Kearney in his studies in the Dismal Swamp region[41] and on Ocracoke Island[42] calls attention to the extremely strong insolation, the periods of intense heat, and the strong currents of air, which together constitute the xerophytic conditions, to which the plants are there exposed on the strand, and which in connection with the unstable condition of the soil are met by certain adaptations in the life-

[39] Cowles, H. C. "The Physiographic Ecology of Chicago and Vicinity." *Bot. Gaz.*, 31: 170, March, 1901.

[40] Ganong, W. F. *l. c.*, pp. 85–87.

[41] Kearney, T. H. "Report on a Botanical Survey of the Dismal Swamp Region." Contrib. U. S. Nat. Herb., V, 367–395, 1901.

[42] Kearney, T. H. "The Plant Covering of Ocracoke Island." Contrib. U. S. Nat. Herb., V, 275–284, 1900.

Between Fog Whistle and the Lake. To the right is drift-beach with the *Cakile-Xanthium* formation. In the middle and to the left is a filled lagoon, the cottonwoods and willows still accumulating the drift-sand. Photo. May 8, 1906.

forms of the plants. Among other such adaptations are mentioned the trailing form of *Strophostyles helvola*, and the radiant form of *Cakile edentula* and of *Euphorbia polygonifolia*. On the drift-beach at Presque Isle *Xanthium*, ordinarily, and *Cenchrus*, often, shows the radiant life-form. This form is chiefly exhibited by annuals with a well defined tap-root and a stem branching immediately above the surface of the ground, the lower branches, at least, lying on the surface of the ground and spreading radiately like the spokes of a wheel.

As Kearney further suggests, the trailing and radiant forms are better fitted by their closely appressed lower branches to shade the soil, thus conserving its moisture, and also to prevent undue exposure to the heat and light reflected from the sand beneath, as well as to prevent so free a circulation of air through the foliage. In this way transpiration is probably considerably lessened, and on account of the protection afforded by the form of the plant the soil is not so readily blown away from the roots by the wind.

Succulent leaves are, of course, a further protection against excessive transpiration and the injurious effects of high insolation, and it is to be noticed that such leaf-forms are almost a universal characteristic of the plants of the *Cakile-Xanthium* formation. This leaf-form is further accompanied by light-colored, insolation-reflecting foliage in *Cakile*, *Xanthium*, *Euphorbia*, and to some extent in *Strophostyles*.

The Sand-plain. —The *Artemisia-Panicum* Formation.

At the eastern end of the peninsula, extending above and beyond the drift-beach, is an area of between two and three square miles of dry, comparatively level sand-plain, which has been gradually built up by drifting sand as the beach has been formed farther and farther lakeward. Towards the southeast this sand-plain contains a number of lagoons or ponds, and is more prominently strewn with logs and driftwood, but from the immediate vicinity of the Key Post, and extending towards the north and west, the sand has been drifted in so abundantly as to have filled the ponds and to have buried the driftwood (see Plate XXVII), the surface thus presenting here a uniformly level plain with the exception of a few small sand-ridges and dunes. It is this latter portion of the sand-plain which is to be considered in connection with the succession under discussion. The two portions of the sand-plain are, of course, essentially similar in their physio-

graphic origin, but, as will be pointed out later, the more northern portion is characterized by different plant-formations from those of the southern portion. The northern portion of the sand-plain has a soil coarser in texture, with a greater exposure to stronger air-currents, thus constituting a habitat with a more unstable soil and more xerophytic ecological conditions.

There is no distinct line of demarcation between the drift-beach and the sand-plain, the one shading off gradually into the other, the theoretical limit of the drift-beach being, however, the extreme limit of waves during winter storms. As the beach grows outward it is being continually built up in the rear, burying the driftwood more or less completely and eventually attaining a height beyond the reach of the waves. Much of the sand-plain is very little higher than the drift-beach and in places the drift-beach appears to have been covered and again exposed by the drifting away of the sand. Such areas of beach again exposed, after having been once buried by the sand, have been termed "fossil beaches,"[43] but, as they present at Presque Isle ecological conditions practically no different than those obtaining in many parts of the sand-plain proper, they will be considered as component parts of the sand-plain habitat.

Areas practically synonymous with the sand-plain, as herein recognized, have been variously denominated as the "*back strand*," MacMillan;[44] the "*upper beach*," Cowles;[45] the "*grass plain*," Ganong;[46] and in a more general sense have been included in the area of the "*dunes*," Schimper;[47] or "*middle dunes*," Kearney.[48] The North Haven Sand-plains as described by Britten,[49] are in part also typical of the sand-plain as herein described. Gleason's "*blowout association*" habitat[50] of the Illinois River Valley sand region is almost an

[43] Cowles, H. C. *l. c. Bot. Gaz.*, 27: 173–175, March, 1899; Whitford, H. N. "The Genetic Development of the Forests of Northern Michigan." *Bot. Gaz.*, 31: 297–298, May, 1901.

[44] MacMillan, Conway. *l. c.*, pp. 973–987.

[45] Cowles, H. C. *l. c. Bot. Gaz.*, 27: 167–173, March, 1899.

[46] Ganong, W. F. *l. c.*, pp. 88–94.

[47] Schimper, A. F. W. *l. c.*, pp. 654–655.

[48] Kearney, T. H. *l. c.* Contrib. U. S. Nat. Herb., 5: 367–395.

[49] Britten, W. E. "Vegetation of the North Haven Sand-Plains." *Bull. Torrey Bot. Club*, 30: 571–620, November, 1903.

[50] Gleason, H. A. "A Botanical Survey of the Illinois River Valley Sand Region." *Bull. Ill. St. Lab. Nat. Hist.*, 7: 149–194, January, 1907.

exact repetition of large parts of the Presque Isle sand-plain, especially towards the southern part.

The ecological conditions on the sand-plain are in some respects somewhat less severe than on the drift-beach. One great difference lies in the freedom of the sand-plain from wave-action; a condition which permits the establishment of biennials or perennials, which perhaps might otherwise be able to endure the conditions obtaining in the drift-beach. Further the sand-plain, being somewhat removed from the lake, and in places being somewhat sheltered by dunes and ridges, is more or less protected from the force of the wind, and on the whole is probably less xerophytic.

The soil of the sand-plain becomes with age more compact by settling and by the sifting in and washing down by rain of the finer particles of sand. At the same time humus is gradually accumulating and so the general tendency of the soil is towards a greater capillary capacity for water and a larger supply of available plant-food. Wherever, because of certain conditions of wind- or wave-action, there has been an accumulation of coarser sand or gravel in the surface layers of the soil, the accumulation of humus and the filling up of the soil with finer particles will take a much longer period, and during this period more xerophytic conditions will prevail.

The soil of that portion of the sand-plain included in the present discussion is apparently, as a whole, of a considerably coarser texture than is the soil of that part of the plain lying to the south of the Key Post. This condition results quite naturally from the physiographic mode of formation of the peninsula; the direction of the drift of the beach-debris being from the southwest and the coarser particles traveling more slowly, the result is that in rounding the end of the peninsula the coarser particles are left behind and so have contributed to the growth of the more northern portion, while the finer material has traveled farther and has contributed to the growth of the shore farther to the southeast.

The water of the coarser sandy or gravelly soil is more largely gravitational and escapes quickly by percolation, following which the air under the pressure of the strong winds circulates freely through the larger air spaces, thus bringing about a somewhat greater evaporation of the scant capillary water and also a rapid direct oxidation (*eremacausis*) of the little organic matter which may have accumulated. The circulation of the air of the soil and also, indirectly, the denitrification

of the soil and the evaporation of the capillary water must be greatly augmented by the great extremes of temperature through which the soil often passes.[51] Such a soil on Presque Isle becomes fitted for plant-life much more slowly than does a soil of finer texture.

(The Formation.)

The ecological formation correlated with the sand-plain habitat may, from its dominant species, be called the *Artemisia-Panicum* formation. It is an open formation, the plants occupying approximately 20 per cent. of the entire area of the habitat. Towards the lake the percentage of area covered is much less than farther back, although in certain areas the plants may be considerably more aggregated, especially in the older portion of the sand-plain near Long Ridge, where the plants may even approximate closed conditions (see Plate XXVIII). In the formation as a whole, however, there is practically no competition among the component species, the biological element being of little importance in the ensemble of ecological conditions.

The facies of the formation is determined mainly by *Artemisia* — *A. canadensis* and *A. caudata* — and *Panicum virgatum*, but there is considerable alternation among these and a few other prominent species, so that several consocies are to be recognized. There is also considerable evidence of a succession among what are to be recognized as consocies, as one goes from the youngest to the oldest parts of the habitat.

In the youngest part of the habitat, that nearest the drift-beach, the formation consists essentially of the following consocies:

(*a*) *Panicum-Artemisia* Consocies.
(*b*) *Andropogon furcatus* Consocies.
(*c*) *Cladonia* Consocies.

[51] On the sand-plain at Cedar Point under almost exactly the same conditions as may be found in various places on the sand-plain at Presque Isle, the author found the temperature at a depth of one half inch below the surface of the sand, at 1:30 P. M. on a clear hot August day to be 142° Fahr. The temperature recorded at the Weather Bureau, at Sandusky, just across the Bay, was 79° Fahr., maximum for the day. The spot at which these measurements were taken was somewhat protected from the slight breeze by a few surrounding oaks.

See Jennings, O. E. "An Ecological Classification of the Vegetation of Cedar Point." *Ohio Naturalist*, 8: 291–340, April, 1908.

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Plate XXVIII

Looking across the sand-plain from the western part of Long Ridge. *Panicum-Artemisia* formation with a community of *Arctostaphylos* heath in left foreground, in center a *Myrica* thicket, in left background a *Juglans cinerea*; other trees *Populus deltoides*. Photographed May 8, 1906.

Each of the above mentioned consocies may occur over a certain area with the facies alone, but over much of the habitat there is more or less of a commingling of the different facies. The *Panicum-Artemisia* consocies occupies a large part of the southern and middle portion of the habitat, reaching out to the drift-beach in many places towards the south, and being replaced towards Long Ridge very largely by the *Andropogon furcatus* consocies.

In some of the most exposed parts of the habitat, and where the wind has a clear sweep, is to be found the *Cladonia* consocies. The latter consocies certainly plays a considerable part as a sand-binder and probably prepares the way for colonization by other plants. With the *Cladonia* is associated *Ceratodon purpureus*, occurring mainly as little flat concentric disks, sometimes attaining a diameter of six inches before the central portion dies and the family becomes a community. As a sand-binder the moss must also be of considerable importance, especially when abundant, as in a number of small areas. Each moss disk acts as an obstruction, behind which the sand can be seen collecting in a miniature dune.[58]

Principal Species. — The principal species to be noticed in the *Panicum-Artemisia* formation are *Lathyrus maritimus*, *Solidago nemoralis*, and *Aster ericoides*. *Lathyrus maritimus* has a mode of dissemination much different from that of the facies mentioned. Its diseminules are not readily blown about and promiscuously scattered by the wind, and the structure of the *Lathyrus* associations is more properly to be approached from the standpoint of aggregation; the groups thus being recognized as family, community, or society, according to the extent of the aggregation.

A few plants stray into the sand-plain habitat from the drift-beach, such as *Xanthium*, *Cakile* and *Strophostyles*, but they occur only in the part immediately adjoining that habitat, never in the older part of the sand-plain near Long Ridge.

Secondary Species. — Occurring apparently promiscuously in the consocies mentioned above are the following secondary species:

Euphorbia polygonifolia, *Onagra Oakesiana*,
Onagra biennis, *Gnaphalium polycephalum*,
Cenchrus carolinianus.

[58] *Cf.* Warming, E. "Lehrbuch der Oekologischen Pflanzengeographie," pp. 243–244.

One aspect, an autumnal one, is to be noticed in this formation, characterized by *Solidago nemoralis* and *Aster ericoides*, constituting together the *Solidago-Aster* Society. This society is mainly confined to the younger portion of the sand-plain, being better developed in that portion of the plain to the south and reaching its best development in the finer soil south of the Fog Whistle. As compared with the *Solidago nemoralis* growing so abundantly on the hills in the vicinity of Pittsburgh the plants referred to that species on Presque Isle are considerably smaller and have much lighter-colored leaves.

The *Arctostaphylos-Juniperus* Heath Formation.

That part of the sand-plain fronting the northern part of Long Ridge has soil of a somewhat different character from that of the corresponding part of the sand-plain, as it is being formed to-day from the beaches north of the Key Post. This older portion near Long Ridge has a less porous, more compact soil, owing probably in large part to the drifting in of finer particles of sand by the wind, and in part to the agencies of atmospheric disintegration, especially expansion and contraction during the sudden extremes of temperature, to which the sand-plain is exposed, this finally resulting in a splitting up of the gravel into finer particles and at the same time rendering more available a certain amount of mineral plant-food. There is also some humus to be seen in the upper layer of sand where the vegetation has more nearly approached a closed formation. The accumulation of humus is of necessity very slow in such a soil; the scanty plant-covering, the great porosity of the soil, the exposure to strong air currents, and the great extremes of temperature through which the soil passes, all tending to both prevent the accumulation of humus and the retention of the products of the scanty humification.

The habitat of the *Arctostaphylos-Juniperus* heath at present comprises the western portion of Long Ridge, extending east from the immediate vicinity of the Light House for approximately a mile, and also covering adjoining portions of the former sand-plain along the northern side of the Ridge. The term "heath" is here used in the sense employed by several American workers to indicate a xerophytic formation characterized by evergreen shrubs.[53] Cowles, referring to

[53] Cowles, H. C. *l. c. Bot. Gaz.*, 27: 367–369, May, 1899; Cowles, H. C. *l. c. Bot. Gaz.*, 31: 173–174, March, 1901; Brown, F. B. H. "A Botanical

Plate XXIX.

On western end of Long Ridge, showing the *Arctostaphylos-Juniperus* heath formation. Ground covered with *Arctostaphylos*. *Juniperus* numerous; *Pinus Strobus* invading, as in left foreground. Photographed May 8, 1906.

the position of heaths on the windward slopes of the dunes of Lake Michigan, notes that: "The key to these facts is exposure to desiccating factors, especially heat, cold, and winds. . . . There is a vegetation carpet and a covering of humus. Both slopes have a mesophytic soil; the leeward slope has also a mesophytic air, but the windward slope has a xerophytic air." The heath at Presque Isle is characterized, as is also the northwestern portion of the sand-plain, by strong winds and extremes of heat and cold, but, as mentioned in the preceding paragraph, the conditions of the soil have become somewhat more favorable to plant-life than in the sand-plain.

The heath is a closed formation characterized by two facies — *Juniperus virginiana* and *Arctostaphylos Uva-Ursi* (see Plate XXIX). The formation has few secondary species and varies but little from season to season in general appearance. However, in a few places the *Lupinus perennis* Society becomes quite conspicuous in a June Aspect.

Secondary Species. —

Geaster hygrometricus,	*Andropogon furcatus*,
Poa pratensis,	*Lithospermum Gmelini*,
Pinus Strobus,	*Quercus velutina*,
Prunus serotina,	*Celastrus scandens*,
Toxicodendron pubescens,	*Rubus allegheniensis*,
	Rubus occidentalis.

Most of the species included in the above list are to be found most abundantly in adjoining formations, where they more properly belong. Some are to be classed as relicts of the preceding formation — *Lithospermum* and *Andropogon*; others are invaders from the thicket formation immediately along the ridge to the east — *Rubus*, *Rhus*, *Celastrus*, and *Prunus*; still others are invaders from the forest formations — *Quercus velutina* and *Pinus Strobus*.

The bearberry (*Arctostaphylos*) spreads quite rapidly in all directions over the sandy soil by means of its long prostrate vegetative shoots, and although during the winter months it usually has an abundance of bright colored berries eaten by birds, to which some of its

Survey of the Huron River Valley, III." *Bot. Gaz.*, 40: 275, October, 1905; Whitford, H. N. "The Genetic Development of the Forests of Northern Michigan." *Bot. Gaz.*, 31: 298–299, May, 1901; *and* Adams, C. C. "An Ecological Survey in Northern Michigan." Rpt. Mich. State Bd. of Geol. Survey, 1905: 24, 1906.

dissemination must be ascribed, most of the territory included each year by the plants is that taken in by the radiate enlargement of the parent plant. Isolated plants, families, or even communities, are to be found out on the sand-plain in advance of the heath, and have evidently been distributed by birds, but such occurrences are comparatively rare. Such isolated occurrences of the plant are necessary, however, for the advance of the formation sufficient to keep up with the forward march of the other formations. The vegetative method of dissemination would, at the most, advance the plant not more than two or three feet in a season.

With the red cedar (*Juniperus virginiana*) the conditions of dissemination are quite different. Occasional isolated specimens of this species occur far out on the sand-plain in such positions that they plainly indicate dispersal of the seeds by birds. On the sand-plain such specimens almost invariably stand on the leeward side (east) of a cottonwood trunk (see Plate XXX). The most abundant reproduction of the red cedar, however, occurs in the *Arctostaphylos* mats where it apparently finds conditions better suited for its ecesis. As conditions are at present in the heath, the relative predominance of *Arctostaphylos* and *Juniperus*, as to the number of individuals and as to the area occupied, is decidedly in favor of the former species in the younger stages of the formation and of the latter species in the older stages. At the climax of the formation the *Juniperus* occupies about 80 per cent of the total area.

The reaction of the heath upon the edaphic conditions of the habitat is, as compared with such effects in most formations, very rapid. This reaction consists mainly in the accumulation of humus. *Arctostaphylos* forms over the surface of the sand an entangled mat which very effectually catches and retains its own leaves when shed, as well as leaves which are blown over from the forest to the west or southwest. The soil being protected, both by the *Arctostaphylos* mat and by the dense compact *Juniperus* acting as a windbreak, humification rather than eremacausis becomes the rule, and there is an annual accumulation of humus and fine sand, blown in by northerly and northeasterly gales, finally resulting in a layer above the sand of a fine sandy loam. As compared with the soil of the almost bare sand-plain we have in the soil of the heath much better conditions of available moisture for plants (capillary and hygroscopic moisture), and excessive aeration is prevented by the vegetational covering, as well as by the fine sandy loam,

Plate XXX.

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Looking east along the northern slope of the western end of Long Ridge. Vernal aspect of *Andropogon furcatus* consocies, as characterized by the *Lupinus perennis* society. *Toxicodendron* thicket on top of ridge to right, *Juniperus* to leeward of *Populus*. *Pinus* seedlings in foreground. Photographed May 15, 1905.

Geaster hygrometricus in northwestern portion of sand-plain. *Panicum Scribnerianum* in left foreground. Note accumulation of vegetable debris, *Populus* leaves and *Panicum* stems and leaves. Photographed May 8, 1906.

acting as a mulch. The temperature of the soil is much more uniform than on the exposed sand-plain; especially are the maximum temperatures much reduced. The liberation of carbon-dioxide during the process of humification also probably results, in connection with humic acids, in the formation of appreciable amounts of carbonates, humates, silicates, etc., which in solution in the capillary water of the soil are available as plant-food. The formation of the various mineral plant-foods in this manner is rendered more probable by the variety of minerals represented in the sand, feldspar, hornblende, gneiss, mica, magnetite, etc., derived mainly from the glacial till, which covers the land along the shores of Lake Erie.

There must be a considerable growth of fungal mycelium throughout the layer of sandy loam, as the *Geaster* is quite abundant and well distributed in the formation (see Plate XXXI). The presence of *Lupinus* with an abundance of root-nodules points to the fixation of atmospheric nitrogen, and the bacteria, which must accompany the humus, must finally indicate the formation of nitrates in the soil.

To briefly recapitulate: the soil of the heath as compared with the soil of the sand-plain is more stable; is more uniform in temperature and moisture; is less excessively aerated; has greater capillary and hygroscopic capacity attended by less rapid leaching; has an upper layer of sandy loam, acting as a mulch; eremacausis is very slight, if present at all; but humification and nitrification must occur, indirectly resulting in the production of various salts available as plant-food.

The *Pinus Strobus* Formation.

As stated in the preceding discussion the mature heath has reacted upon its ecological environment to a quite marked extent, and in so doing it has at the same time brought about certain conditions suitable to other species, which will thus be able to eventually replace the heath-formation. *Juniperus virginiana* and *Arctostaphylos Uva-Ursi* can accomplish ecesis and thrive in dry sandy or gravelly soils,[54] or on dry limestone hills or barren flats, in the case of *Juniperus*;[55] or in dry sands and on exposed xerophytic mountain-tops, in the case of *Arctostaphylos*.[56] So it is, also, to a less extent, with *Pinus Strobus*.

The white pine, throughout its range, whether on islands in a

[54] Britten, W. E. *l. c.*

[55] Mohr, Charles. "Notes on the Red Cedar." U. S. Dept. Agricul., Div. Forestry, Bull. 31: 28, 1901, *and* Adams, C. C. *l. c.*, pp. 24, 29, etc.

tamarack swamp, sandy soils along the Great Lakes, rocky mountains, or gravelly moraines, owes its prominence there to its ability to thrive in light, infertile, and semi-xerophytic soils. Wherever the ecological conditions are suitable for the growth of more mesophytic trees the white pine is likely to succumb to competition; even though its germination may be successful its seedlings cannot endure the dense shade of hemlock or of most hardwood forests.

The winged seeds of the white pine are often blown for a considerable distance by strong winds and, as the white pine woods lie immediately to the southwest of the heath at Presque Isle, many white pine seeds find lodgment in the tangled mat of bearberry (see Plates XXIV, XXIX and XXX). There they find in the sandy loam the very best conditions for ecesis, viz., moderate moisture and a low open vegetational covering, which gives protection from the extremes of heat and drought, and yet lets in the rather abundant light, which is believed to be so essential for the white pine seedlings. Many seeds of the white pine undoubtedly find lodgment in the soil of the sand-plain, but although germination might be successful in certain wet periods, the seedlings could never endure the heat and drought to which they would be exposed. Certain other formations on Presque Isle, however, as the Myrica-thicket and Cranberry-formations, to be discussed later, offer conditions such that a partial occupation by white pine may take place. In no case, however, on Presque Isle does the white pine accomplish ecesis without the presence of more or less humus in the soil, and without the protection afforded by some low shrubby growth of vegetation.[57]

(The Formation.)

From what has been said it may naturally be inferred that the heath may eventually be crowded out by the ever-increasing number of white pines, and such is actually the case. A pure white pine forest (the *Pinus Strobus* formation) lies immediately to the south of the Light House (see Plate XXXII) and occupies a considerable portion of the area contiguous to the western end of Cranberry Pond. Along the shore to the southwest of the Light House this forest ex-

[56] Spring, S. N. "The Natural Replacement of White Pine on the Old Fields of New England." U. S. Dept. Agricul., Div. Forestry, Bull. 63: 11, 1905.

[57] *Cf.* Livingston, B. E. "The Relation of Soils to Natural Vegetation in Roscommon and Crawford Counties, Michigan." *Bot. Gaz.*, 39: 31, January, 1905.

Pinus Strobus forest formation southwest of Lighthouse. Young *Quercus velutina* in middle foreground. Undergrowth of *Viburnum acerifolium, unifolium, Osmunda, Vaguera*, etc. Photographed September 20, 1906.

tends out to the open slope leading directly down to the waters of the lake, and which marks the extent to which the lake had worn away the land prior to the erection of the jetties by the government. At the summit of this slope there are, in a few places, small patches of *Arctostaphylos*, and some *Juniperus*, representing remnants of the heath, but the invasion by the *Pinus Strobus* formation usually begins quite early in the life of the heath and, as a result, the pine forest presents along this part of the shore an almost unbroken front.

In the most northwesterly and xerophytic portion of the pine forest there is practically no outer shrub zone, other than the heath, but farther inland to the east, where the exposure to the lake winds is not so great, the conditions are more mesophytic and there is a gradual transition into what may be called a mixed formation in which species of *Prunus*, *Acer*, etc., are prominent. A discussion of this formation will be taken up later.

In the *Pinus Strobus* forest formation there is comparatively very little of the *layering* which is so characteristic of most hardwood forests. There are in places a very few trees of the wild black cherry, *Prunus serotina*, also *P. pennsylvanica*, which are generally of about the same height as the pines and are being gradually killed out by their dense shade. *Juniperus virginiana* occurs occasionally as a relict from the heath, but it apparently does not accomplish ecesis in the white pine forest.

There are but few seedlings of white pine in the typical part of the formation. It appears that at Presque Isle, as has been found elsewhere,[38] the seedlings of the white pine cannot endure the dense shade of the mature white pine forest. If other trees are available which can endure this shade during the seedling stages the white pine will finally be replaced by a forest of other species. At Presque Isle the black oak, *Quercus velutina*, is present very sparingly as a seedling in the heath, but it becomes more and more abundant in all sizes as the mature pine forest is approached and, upon the death of the white pine, its place is occupied by black oak. Black oak appears to be capable of accomplishing ecesis without difficulty, both in the heath and in the dense pine forest; its appearance in the latter in greater numbers being due to circumstances of dissemination rather than to its particular adaptability to the habitat. Some acorns may reach the sand-plain also, but as Britten found on the North Haven Sand-

[38] Spring, S. N. *l. c.*, p. 20.

plains,[59] the seedling fails to find there the necessary moisture and never succeeds.

In the *Pinus Strobus* formation the shrub, herbaceous, and ground-layers consist of scattering individuals of the following species:

Smilax herbacea,	*Vaccinium corymbosum,*
Cypripedium acaule,	*Lycopodium clavatum,*
Pyrola americana,	*Lycopodium complanatum,*
Pyrola elliptica,	*Lycopodium lucidulum,*
Pyrola secunda,	*Lycopodium obscurum,*
Chimaphila maculata,	*Unifolium canadense,*
Chimaphila umbellata,	*Vagnera stellata,*

Morchella esculenta.

The reaction of the *Pinus Strobus* formation upon its habitat is probably relatively greater than that of the heath, but it consumes a much longer period of time. The heath, as indicated by the relative sizes of the junipers, ordinarily occupies its habitat not more than thirty years before being replaced by the *Pinus Strobus* formation, while the latter occupies its habitat for approximately two hundred years. The soil in the pine forest is everywhere covered with a layer of pine needles and in the older portions of the forest, beneath the upper layer of undecayed needles, is a layer of more or less completely humified organic material often more than one inch in thickness. The line of demarcation between the lower part of this layer, which represents the sandy loam of the heath, is not so distinct as in the heath, owing probably to the decay of roots and fungal mycelia, and perhaps indirectly to some extent to the percolation of hydrostatic water. The action of earthworms, so important in many soils, is not indicated in this soil.

The accumulation of a mulch of forest litter, a thick layer of humus, and the gradual distribution of humus throughout the sand beneath, are processes tending directly or indirectly to increased capillarity, humification, nitrification, the formation of various acids, and the further decomposition of the grains of sand with the production of salts available in solution in the water of the soil as plant-food. The soil, as left by the *Pinus Strobus* formation, as compared with the soil as left by the *Arctostaphylos-Juniperus* heath has a more uniform supply of available (capillary) moisture and also a greater supply of mineral

[59] Britten, W. E. *l. c.*, pp. 578 and 579.

Northwest shore of Presque Isle, looking northwest from Jetty No. 3. The peninsula is here being washed away; note truncate ends of Ridges 5 and 6. The forest is here the *Quercus velutina* formation. Photographed September 20, 1906.

salts. Physically the temperatures prevailing both in the soil and in the air above the soil are more uniform, the aeration is much less, and the light is very much weaker in the *Pinus Strobus* formation.

The *Quercus velutina* Forest Formation.

The gradual invasion of the pine forest by the black oak (*Quercus velutina*) and finally the dying off of the pines, as they approach old age, eventually results in a forest characterized by one facies, the black oak, and hence to be called the *Quercus velutina* forest formation (see Plates XXV and XXXIII). The black oak constitutes usually from 85 to 95 per cent. of the primary layer in this forest and associated with it are scattering individuals of the following species:

Pinus Strobus,	*Tilia americana,*
Quercus rubra,	*Acer saccharinum,*
Quercus palustris,	*Sassafras Sassafras,*
Quercus borealis,	*Tsuga canadensis.*

The abrupt change in the character of the foliage canopy from the dense, dark, evergreen pine woods to the light, deciduous, black oak forest makes a very marked difference in the conditions of the habitat with reference to insolation in the layers below the facies of the formation, and the response to the changed environment is correspondingly very plainly evident.

Below the primary layer the four layers following are to be distinguished:

The Secondary Layer. — The secondary layer is composed of small trees and larger shrubs of varying sizes, consisting essentially of smaller individuals of the species represented in the primary layer. It is noteworthy in this connection, however, that there are relatively more white pine saplings in this formation than in the *Pinus Strobus* formation. The light conditions more nearly approximate to those of the heath formation than to those of the pine forest. The result is to a limited extent indicative of a possible alternation of formations.

The Tertiary Layer. — The tertiary layer consists of small shrubs and bushes, which owing to the presence of much *Smilax* become in places a tangled mass very difficult to traverse. The species represented in this layer are as follows:

Smilax herbacea,	*Aralia racemosa,*

Toxicodendron pubescens, *Vitis vulpina*,
Rubus allegheniensis *Celastrus scandens*,
Diervilla Diervilla.

The Herbaceous Layer. — The fourth layer consists of herbaceous plants of various species, which usually alternate to some extent with the layer next above, forming where not too much shaded a more or less dense carpet of vegetation. The species are as follows:

Corallorhiza maculata, *Chimaphila maculata*,
Aralia nudicaulis, *Galium circæzans*,
Vagnera stellata, *Hieracium scabrum*,
Vagnera racemosa, *Hieracium Gronovii*,
Unifolium canadense, *Solidago cæsia*,
Meibomia Dillenii, *Helianthus strumosus*,
Lespedeza capitata, *Tussilago Farfara*,
Osmorhiza Claytoni.

A few of the species in the herbaceous layer are of sufficient abundance to dominate during certain aspects. The *Aralia nudicaulis* society, the *Vagnera stellata* society, the *Unifolium canadense* society, and the *Osmorhiza Claytoni* society are especially to be noticed in this connection. Each of them forms over certain areas practically pure groups of one species alone. A comparatively large proportion of the species of the herbaceous layer depend more or less upon creeping stems or rhizomes for their dissemination, this method being especially favored by reason of the loose soil, in which the plant-food is largely in the upper layers. The result of this method of dissemination is, of course, a more definite alternation of different species into groups having the rank of family, community, or society.

The Ground Layer. — The ground layer is very poor as to lichens and mosses, but of the fungi, especially the Agaricaceæ, there were at times a considerable number to be seen. On account of inadequate facilities for drying the specimens during rainy weather many of the collections were lost, but the following were among the more abundant species in the habitat:

Russula virescens, *Amanitopsis vaginata*,
Russula emetica, *Armillaria mellea*,
Lactarius piperatus, *Lentinus lepidus*,
Amanita verna, *Lycoperdon gemmatum*,

Collybia radicata, *Mycena acicula*,
Boletus sp., *Scleroderma vulgare*,
Cortinarius sp.

The reaction of the *Quercus velutina* formation upon its habitat consists mainly in the addition of more humus to the surface layers, and by means of the roots to the soil for some distance below the surface. Along the lake-front there is now a recession of the shore, so that the waves of the ordinary summer storms reach to the base of a perpendicular cliff of sand which is continually being washed out below and thus undermining the oak forest and causing the trees to topple over into the lake. The side of the cliff shows the trees to be very profusely but shallowly rooted, practically the entire root-system being usually in the upper three feet of soil. The soil, however, is visibly stained with humus to a depth of a foot or more below this.

That the *Quercus velutina* formation is the climax-stage in the Beach-Sand Plain-Heath-Forest Succession is probably not the case, but it does appear that the *Quercus velutina* formation would persist as such for a long period. Owing to the physiographic changes in the northwestern shore of the peninsula, in which the land has been continually worn away by the lake, it appears that none of the *Quercus velutina* formation which can be definitely said to have followed the heath through the pine stage has attained any great age, it having been washed away. Probably in the course of time the conditions of moisture and available plant-food might become so changed through agencies of disintegration and the accumulation of humus that other more mesophytic trees might be able to compete successfully with the oaks, or to replace them altogether.

In various parts of the northeastern United States there are to be found sandy soils resembling quite closely the soil of the *Quercus velutina* habitat at Presque Isle. At Cedar Point, Sandusky, Ohio, the buildings of the Cedar Point Resort Company occupy a portion of the peninsula which is almost an exact counterpart of the *Quercus velutina* habitat at Presque Isle and the close similarity extends also to the formation. In the North Haven Sand-plains, in Connecticut, the black oak, although scattering, is yet the predominant tree.[60] Brown designates the formation occurring on the comparatively arid upper slopes of a sandy bluff at Ypsilanti, Michigan, as the "Black Oak Society,"

[60] Britten, W. E. *l. c.*, pp. 578–579.

"53 per cent of the individuals on the slope above the 760-foot contour line being black oaks."[61] Cowles finds, near Chicago, the black oak predominating on the south slopes of the established sand-dunes and on the higher sandy ridges and beaches of glacial origin.[62] Cowles further says: "The future of the vegetation on the established dunes and beaches is somewhat problematical. From analogy with other plant-societies in this region, and from established dunes in Michigan, we should expect a mesophytic forest, probably of the white oak-red oak-hickory type at first and then followed by a beech-maple forest."

The predominance of the black oak, rather than other hard woods of the region, as a successor to the white pine is, perhaps, partly to be explained by the fact that the black oak is of a more xerophytic habit and, partly, by the fact that "The percentage of ash in the wood of such trees as form the principal covering of a dune region is relatively small. As seen in the analyses reported in the volume of the Tenth Census on the forest trees of North America, the pines have an average range of .19 to .23 per cent. The two most common oaks, *Q. velutina* and *Q. coccinea*, have .28 and .19 per cent. respectively."[63] The white oak, burr oak, beech, sugar maple, basswood, and hemlock have a considerably higher per cent. and are less common or wholly absent in such sandy areas.

Livingston's conclusions with regard to the relations of soils to vegetation in certain portions of Michigan would apply also to the distribution of the plant-formations on Presque Isle. Livingston's conclusions are briefly that "the main factor in determining the distribution of forests on the uplands of this region is that of the size of the soil particles."[64] This factor determines directly the amount of air in the soil, and thus indirectly the extent of formation of humus, nitrates, and other soluble salts.

THE BEACH-SAND PLAIN-THICKET-FOREST SUCCESSION.

The Beach-Sand Plain-Thicket-Forest Succession is very closely related to the Beach-Sand Plain-Heath-Forest Succession just described, but it nevertheless differs from the latter so radically, that it seems best to give it a distinct rank.

[61] Brown, F. B. H. "A Botanical Survey of the Huron River Valley, III." *Bot. Gaz.*, 40: 274–275, October, 1905.

[62] Cowles, H. C. *l. c. Bot. Gaz.*, 31: 174–177, March, 1901.

[63] Hill, E. J. "Flora of the White Lake Region, Michigan, and its Ecological Relations." *Bot. Gaz.*, 29: 434, June, 1900.

[64] Livingston, B. E. *l. c.*, p. 40.

This succession comprises a total area about equal to the succession just described, but it is considerably broken up by ponds and lagoons, so that it is scattered over a region much larger. Beginning near the Key Post it extends to the east and southeast of the Beach-Sand Plain-Heath-Forest Succession, reaching in the one direction to the U. S. North Pier and in the other direction to Presque Isle Bay, extending southwestward to the Chimney Ponds.

The initial and final stages in the two successions are much more similar than are the intermediate stages. As will be discussed farther on, the intermediate stages represented by the heath and the white pine forest are really formations derived from a distinct forest center, and therefore representing altogether another succession than the intermediate stages in the succession under discussion. The presence of stages of another succession, belonging to a distinct forest center, indicates some considerable difference in the ecological conditions obtaining in the habitat, and this difference is probably that of different conditions of soil moisture. The amount of soil moisture depends mainly upon the physical texture of the soil, particularly the size of the soil particles, and also upon the amount of humus present. The more northern and lakeward portion of the peninsula is built up of the coarser deposits of the eastward running littoral current, thus a coarser soil occurs here with less capillary moisture and more xerophytic conditions.

The amount of moisture in the soil being different in the two habitats, there might be expected to occur a corresponding difference throughout the entire successions, but in the initial stages of the successions there is practically no humus in the habitat, and the exposure is in both cases so severe that the corresponding formations are practically identical. In the final stages, on the other hand, the humus has accumulated in both habitats to such an extent as to bring about very similar edaphic conditions, thus permitting the occupancy of the two habitats by the same formations. It is only in the intermediate stages of the successions, where the conditions of exposure and the content of the humus differ considerably, that differences of corresponding stages in the formations may occur.

The Lower Beach. — The *Chlamydomonas* Formation.

The Lower Beach of this succession although consisting mainly of finer sand differs in no respect as to vegetation from the lower beach of the more westerly succession. A few sporadic patches of *Chlamydomonas* were observed.

The Drift-beach. — The *Cakile-Xanthium* Formation.

The Drift-beach and its formation correspond here very closely to the homologous structures occurring to the west of the Fog Whistle, but the effect of the prevailing currents in times of the heaviest surf in carrying the disseminules of various plants to the east and southeast and also, perhaps, the less direct exposure to the prevailing cold westerly winds, is to be seen in the greater abundance of plant-life towards the southeast. The same species constitute the formation in both successions, but they are all, especially *Strophostyles helvola*, much more abundant towards the southeastern extremity of the beach.

The accumulation of drift is considerably greater in this habitat than it is to the northwestward, and, although by far the greater portion of this organic material probably undergoes eremacausis, some humification may occur and may have some part in bringing about a greater abundance of plant-life in this locality. A more important factor is probably the protection afforded many of the seedlings by the driftwood.

The Sand-plain. — The *Panicum-Artemisia* Formation.

In the Sand-plain southeast of the Fog Whistle the habitat differs again very little from its homolog to the east, except in the presence of more driftwood and a finer soil texture. There is thus more soil moisture, and, because of the presence of the driftwood and the proximity of forest to the south and southwest, there is somewhat more protection from the cold winds than is the case in the more eastern sand-plain.

Listing the consocies of the *Panicum-Artemisia* formation in this habitat there are the following:

(*a*) *Panicum-Artemisia* Consocies,
(*b*) *Andropogon furcatus* Consocies,
(*c*) *Stenophyllus capillaris* Consocies,

Plate XXXIV.

Vernal aspect of the *Panicum-Artemisia* formation as characterized by the *Arabis lyrata* society. Young *Myrica* thicket in the immediate background. Photographed May 10, 1907.

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(*d*) *Sorghastrum nutans* Consocies,
(*e*) *Cladonia* Consocies,
(*f*) *Polytrichum* Consocies.

Most of the above consocies may appear pure, and over considerable areas may consist of the facies alone, but usually several of the facies are promiscuously scattered about, forming a mixed open structure. The *Panicum-Artemisia* consocies occupies more generally the open, more exposed positions nearer the lake, while in the most exposed of the more inland parts of the habitat occurs the *Cladonia* consocies. Areas apparently lowered nearer to the water-table by the drifting away of the sand ("fossil beaches," or "blow-outs") are usually occupied by either the *Stenophyllus capillaris* consocies, the *Sorghastrum nutans* consocies, or by the *Polytrichum* consocies, the different consocies being commingled or occurring alone. *Polytrichum* sometimes forms a pure carpet, and, where occurring with *Stenophyllus*, often crowds out that species altogether, bringing on the final appearance of a heath. The formation of humus with either *Stenophyllus* or *Polytrichum* is quite rapid, the organic matter and indrifting sand being bound firmly together by the roots and rhizoids. Inland, towards Long Ridge, the *Andropogon furcatus* consocies becomes more and more abundant, usually replacing the *Panicum-Artemisia* consocies altogether as the forest is approached.

Principal Species of the Panicum-Artemisia Formation. —

Lathyrus maritimus,	*Aster ericoides*,
Solidago nemoralis,	*Arabis lyrata*.

In the smaller areas of the sand-plain between the lagoons and marshes near the southern end of the extension of Long Ridge and northwest of Horse-Shoe Pond the force of the winds is much broken by the quite abundant thickets and cottonwood trees, and in these sheltered positions occurs the *Arabis lyrata* society, which determines thus a vernal aspect, being usually in full bloom on May 15 (see Plate XXXIV). Associated with *Arabis* as secondary species are *Moehringia lateriflora* and *Arenaria serpyllifolia*. During the period of bloom of *Arabis* the society is quite conspicuous, appearing during that aspect as a prominent part of the formation.

The *Lathyrus maritimus* society occurs mainly in the new soil a short distance back from the drift-beach and usually more or less in

the shelter of driftwood. The society becomes quite conspicuous during the time of blooming of the *Lathyrus*, when the ends of the branches assume a more or less upright position. The plant blooms continuously from early June to late August or September.

The *Solidago nemoralis* society, together with the *Aster ericoides* society, characterize the autumnal aspect in the lakeward half of the habitat of the formation. These societies are usually associated with the *Panicum-Artemisia* consocies. There is often a distinct zonation in the distribution of the *Solidago nemoralis*, it forming a rather broad band just outside of the zone of cottonwoods, the latter forming the outer boundary of the lagoon vegetation. The only plausible explanation suggesting itself is that there may be more suitable conditions of moisture at these places, although the surface of the sand-plain is usually at the same elevation as farther back in the *Panicum-Artemisia* habitat.

Secondary Species of the Panicum-Artemisia Formation. —

Euphorbia polygonifolia,	*Onagra biennis*,
Gnaphalium polycephalum,	*Onagra Oakesiana*,
Cenchrus carolinianus,	*Lupinus perennis*,
Cyperus Schweinitzii,	*Polygala verticillata*,
Cyperus filiculmis,	*Moehringia lateriflora*,
Arenaria serpyllifolia,	*Panicum Scribnerianum*,
Asclepias Syriaca,	*Lithospermum Gmelini*,
Salix syrticola,	*Fragaria virginiana*,
Prunus pumila,	*Psilocybe ammophilus*,
Geaster hygrometricus,	*Marasmius* sp.

The distribution of the secondary species among the different consocies is mainly as follows, most of the species exhibiting a preference for some one particular consocies:

In the *Panicum-Artemisia* consocies —

Euphorbia polygonifolia,	*Gnaphalium polycephalum*,
Onagra biennis,	*Cenchrus carolinianus*,
Onagra Oakesiana,	*Cyperus Schweinitzii*,
Polygala verticillata,	*Moehringia lateriflora*,
Arenaria serpyllifolia,	*Salix syrticola*,

Prunus pumila.

Plate XXXV.

A community of *Lithospermum Gmelini* in the *Andropogon furcatus* consocies of the *Panicum-Artemisia* formation. The dark-colored objects in the foreground are cushions of a moss, *Ceratodon purpureus*. Photographed June 10, 1906.

In the *Andropogon furcatus* consocies — (see Plate XXXV)

Lupinus perennis, *Panicum Scribnerianum*,
Asclepias syriaca, *Lithospermum Gmelini*,
Geaster hygrometricus.

In the *Stenophyllus capillaris* consocies —

Cyperus filiculmis, *Marasmius* sp.

In the *Sorghastrum nutans* consocies —

Fragaria virginiana.

The *Myrica* Thicket Formation.

Next following the *Panicum-Artemisia* formation comes the thicket-formation, composed of small trees and shrubs, which is in its turn to be finally replaced by a forest-formation. The thicket in this succession is the homologue of the heath in the succession previously described. It begins at about the same distance from the lake, in soil of about the same age, and is, similarly, to be finally replaced by a forest. This formation at Presque Isle may be called the *Myrica*-thicket-formation, its facies being the wax myrtle, *Myrica carolinensis*.

Myrica carolinensis apparently cannot at once accomplish ecesis in the upper layers of dry, loose sand, such as are occupied by the *Panicum-Artemisia*, the *Andropogon furcatus*, or the *Cladonia* consocies, but in the other consocies of the formation, especially in the finer, moister soil occupied by the *Stenophyllus capillaris* or the *Sorghastrum nutans* consocies, the waxy *Myrica* drupes can successfully sprout and give rise to healthy plants. From these plants as centers the *Myrica* may by vegetational reproduction and dissemination invade the dryer soils of the first mentioned consocies. Young shoots of the *Myrica* arise in a radial zone all about the parent plant, having their origin both in lower limbs, which may have become buried in the sand, and also from subterranean branches.

In this manner the *Myrica carolinensis* consocies may in the course of a few years successfully occupy quite extensive areas, displacing not only the *Stenophyllus* and *Sorghastrum*, but also the consocies of more xerophytic habit.

Principal Species of the Myrica Thicket-formation. —

Prunus serotina, *Rubus allegheniensis*,
Prunus pennsylvanica, *Fragaria virginiana*,
Prunus virginiana, *Celastrus scandens*,
Solidago canadensis.

Secondary Species. —

Rhus typhina,	*Rubus occidentalis,*
Alnus incana,	*Juniperus virginiana,*
Vitis vulpina,	*Andropogon furcatus,*

Poa compressa.

Quite conspicuous in the *Myrica* thicket-formation in autumn is the *Solidago canadensis* society, an autumnal aspect thus being characterized. At this time the tall golden-rods considerably overtop the shrubby *Myrica*, and being quite abundant, the effect is often to almost hide the shrubs from view. The difference in the choice of habitats of *Solidago nemoralis* and *S. canadensis* is indeed very striking. Neither species is found to occur in the habitat of the other, although there is often but a very few years intervening between the disappearance of the former and the occupation of the same spot by the latter species. The effect of the thicket-formation upon its habitat is rapid, as is evidenced by the quick change in the species of *Solidago*. The bushy, compact clumps of *Myrica* catch and securely retain vegetable litter, leaves, etc., blown about by the wind, and in a short time a considerable layer of humus is formed. In this manner the ecological conditions soon become favorable to species other than those of the *Myrica* thicket-formation, and in the course of but a few years the thicket will be displaced by a forest-formation.

Ganong notes[65] that on sheltered slopes of the low dune-beaches on the sand-plain of the island of Miscou, in situations similar to those occupied by the low shrubby mats of *Juniperus nana* and *Hudsonia tomentosa*, are patches of "A bright green, leathery-leaved, tufted shrub, the wax-berry, *Myrica carolinensis*, which comes to form discoid (sometimes almost fairy-ring-like) masses on the crests and inner slopes," and he further remarks that the shelter of the shrubby mats formed by this species "Affords in reality the principal starting point for the development of other plants, which lead gradually to the development of the forest."

Kearney, in his description of the "Myrica association" of the "Middle (Open) Dunes" near the Dismal Swamp, says:[66] "In sheltered flat places *Ammophila* sometimes makes a comparatively dense, almost meadow-like growth, often associated with scattered

[65] Ganong, W. F. *l. c.*, pp. 92–93.

[66] Kearney, T. H. "Report on Dismal Swamp." *l. c.*, pp. 370–395.

depauperate shrubs — *Myrica carolinensis, Quercus virginiana maritima, Rhus copallina.* The higher sand-hills are often occupied by dense thickets of *Myrica carolinensis* usually 1½ to 2 meters (5 to 6 feet), but frequently 3 meters (9 feet) high, often unaccompanied by other woody species. This plant, which is more or less at home in the drier portions of the forested plain, is, however, most characteristic as a dune-plant and is noteworthy as the shrub which usually occurs nearest the beach."

At Presque Isle *Myrica* never assumes the rôle of a dune-plant. It rarely seems able to extend itself, even by vegetative dissemination, up to the tops of the ridges and neither do the drupes seem to be capable of successful growth in the drier portions of the sand-plain. Although structurally a xerophyte,[67] and usually occupying quite xerophytic habitats along the Atlantic sea-board, it must be regarded at Presque Isle as being much less xerophytic in habit.

In the advanced stages of the *Myrica* thicket-formation other plants than *Myrica* become more and more prominent, until finally a transitional stage is attained, representing the advanced guard of the coming forest. At this stage the thicket consists typically of the following species:

Rubus allegheniensis,	*Vitis vulpina,*
Rubus occidentalis,	*Celastrus scandens,*
Prunus serotina,	*Prunus pennsylvanica.*

The *Prunus* Forest-formation.

A forest-formation soon displaces the transitional thicket following the *Myrica* thicket-formation. This forest-formation is at present best seen immediately to the west and south of Long Ridge, where it alternates with a formation derived from the *Rhus-Alnus* thicket, to be described in connection with another succession.

Typically the structure of the *Prunus* forest-formation is as follows:

Facies. —

Prunus serotina,	*Prunus pennsylvanica.*

Principal Species. —

Rubus allegheniensis,	*Celastrus scandens,*
Rubus occidentalis,	*Vitis vulpina.*

[67] Kearney, T. H. "Plant-Covering of Ocracoke Island." *l. c.*, p. 294.

Secondary Species. —

Prunus virginiana,	*Alnus incana*,
Fragaria virginiana,	*Juniperus virginiana*,
Acer saccharinum,	*Quercus velutina*,
Toxicodendron pubescens,	*Poa compressa*,
Myrica carolinensis,	*Smilax herbacea*,
Psedera quinquefolia,	*Amelanchier oblongifolia*.

The layering in the *Prunus* forest is rather indefinite, but below the facies are the smaller trees and saplings of the two wild cherries (*Prunus serotina* and *P. pennsylvanica*) together with a considerable number of the secondary species, constituting thus altogether a layer of variable importance throughout the formation. Below this secondary layer is a more definite layer of bushes, the tertiary layer, dominated by *Rubus allegheniensis* and *Rubus occidentalis* and occurring throughout the formation, but best developed in the more open spaces, and tending to form a fringing zone about the edges of the forest. Clambering about quite promiscuously is the *Celastrus scandens* and some *Vitis vulpina* and *Smilax herbacea*, which, together with the clumps of dead and dying *Myrica*, often forms a tangle very difficult to push through.

The herbaceous layer is very poorly developed in this formation, the tertiary layer so completely occupying the habitat. However, *Poa compressa* occurs in the few openings among the bushes and is accompanied sometimes by *Fragaria virginiana*.

The successor to the *Prunus* forest-formation is evident from the seedlings of *Quercus velutina*, which appear early in the life of the formation, and which gradually become more important, until finally the wild cherries are relegated to a minor position. Were it not for the difficulty with which *Quercus* is disseminated, as compared with the species of *Prunus*, the *Myrica* thicket-formation would, undoubtedly, be succeeded directly by a *Quercus* forest.

The *Prunus* forest-formation is evidently the homolog of the *Pinus Strobus* forest-formation, in that it immediately precedes the *Quercus velutina* forest, but, although the habitats are closely similar, the two formations have very few species in common in the lower layers, on account of the difference in the amount of light under the forest canopies.

Mixed *Pinus-Prunus* forest formation along Board Walk near the Lighthouse. *Pinus Strobus*, *Prunus serotina*, and *Rubus nigrobaccus* constitute the larger part of the vegetation. Photographed June 10, 1906.

The *Quercus velutina* Forest-formation.

This formation is so closely similar to the forest-formation following the *Pinus Strobus* forest-formation that its separate treatment is not deemed necessary. The only essential difference noted was the presence of occasional large trees of *Prunus* and *Acer*, relicts of the earlier *Prunus* forest-formation.

Mixed Formations.

To the southwest of the Fog Whistle the *Panicum-Artemisia* formation gives way, near Long Ridge, to a mixed formation representing the overlapping of the heath and the *Myrica* thicket-formations (see Plate XXVIII). Here may be seen a struggle between the two formations sometimes resulting in favor of the one, sometimes of the other. *Juniperus* and *Pinus* here find apparently equally congenial habitats in either the heath or the thicket so that often a patch of *Pinus Strobus* forest may be seen originating in a *Myrica* thicket (see Plate XXIV). There is also a mixing of the principal and secondary species of the two formations, so that in total number of species the mixed formation is richer than either of the pure formations.

Following this mixed heath-thicket-formation, as the structure may be called, comes a mixed forest-formation derived from the *Pinus Strobus* and the *Prunus* forest-formations (see Plate XXXVI). This mixed forest occupies much of the area between Long Ridge and the Yellow and Ridge Ponds (see map of Presque Isle). The disposition of the respective facies is, perhaps, not so much a true mixture as it is a case of promiscuous alternation of various sized clumps of the two formations. The principal and secondary species of each clump are usually those peculiar to the formation represented by the facies of the clump, there being no indiscriminate mingling as in the mixed heath-thicket-formation.

Following the mixed *Pinus-Prunus* forest-formation comes finally the same *Quercus velutina* forest which follows in the normal successions. Such a *Quercus velutina* forest following a mixed *Pinus-Prunus* forest is represented in a limited way south of Cranberry Pond.

THE DUNE-THICKET-FOREST SUCCESSIONS.

Undoubtedly, in no phase of ecology has there been more field work carried on than in the study of the vegetation of sand-dunes.

In America such studies have been made in several localities.[68] The dunes of Lake Michigan have been worked out by Cowles,[69] and, in many respects his descriptions are equally applicable to similar but less pronounced structures at Presque Isle.

The dunes at Presque Isle may be classified as follows:

(*a*) *Populus* dunes or ridges,
(*b*) *Ammophila* dunes,
(*c*) *Andropogon* dunes,
(*d*) *Prunus* dunes,
(*e*) Mixed *Prunus-Smilax* dunes.

The *Populus* Dune-formation.

The cottonwood, *Populus deltoides*, occupies by far the most important position among dune-forming plants at Presque Isle, just as Cowles finds it characterizing the shore of Lake Michigan at many places, especially southward.

During exceptionally heavy storms from the north or northeast the surf often piles up the sand of the shore into sand-bars, which upon the subsidence of the waves may remain more or less permanently above ordinary water-levels (see Plate XXVI). Between such a bar and the shore proper is usually a long narrow pond or lagoon, which may be cut off from the lake by the drifting in of dry sand from the beach, or, possibly, by the closing in of the ends by the waves. At Presque Isle the subsequent history of such a lagoon depends largely upon its size, its position with respect to drifting sand, and the rapidity with which the general shore-line is advancing upon the lake, and so leaving the lagoon inland.

If the lagoon be towards the north or northwest portions of the peninsula the greater exposure to strong winds generally results in a rapid filling even of a large lagoon by drifting sand (see Plate XXVII). Farther to the southeast the lagoon, being less exposed to filling by wind-driven sand, may escape filling, until the general shore-line has advanced lakeward to such a distance as to leave the lagoon inland, where the advancing vegetation more and more prevents

[68] Hill, E. J. *l. c.*, pp. 419–436; Kearney, T. H. "The Plant-Covering of Ocracoke Island," *l. c.*, pp. 270–271; "Botanical Survey of Dismal Swamp," *l. c.*, pp. 368–393; *and* Gleason, H. A. *l. c.*, pp. 141–189.

[69] Cowles, H. C. "Sand-Dunes of Lake Michigan," *l. c.* "Physiographic Ecology of Chicago and Vicinity," *l. c.*

such a drifting of the sand. A glance at the map of the peninsula shows very plainly the preponderance of ponds and lagoons towards the southeastern part of the peninsula.

During the fruiting period of the cottonwood and of the sand-bar willow, *Salix syrticola*, the cottony disseminules of both of these species are blown over the sand-plain in great numbers by the westerly winds, which prevail during fair weather, and the disseminules are thus blown into the ponds and lagoons in such abundance as to collect along the shores in little windrows. The right conditions for successful ecesis, however, are to be found only in the young lagoons near the lake-shore, where the shores of the lagoons are composed of loose, rapidly accumulating sand, in which the seeds quickly become buried and as quickly sprout. Along the shores of the older lagoons the disseminules collect as abundantly, but the shores being composed of more firmly packed sand, the seeds do not become buried and so cannot accomplish ecesis. Along the lake-beach ecesis is effectually prevented by the mechanical violence of the waves.

At Presque Isle it was found that the cottonwoods always sprouted in the loose sandy shore of lagoons not more than three or possibly four years after the separation of the lagoon from the lake. It is interesting to note that Whitford found in the Philippine Islands the "mangrove and *Nipa-Acanthus* formations behind sandy beaches" having methods of dissemination and ecesis very similar to those just described for the *Populus-Salix* formation at Presque Isle. In both instances the disseminules first float upon areas of quiet water protected by bars or beaches and both find the dynamic conditions of the strand too strenuous to admit of their obtaining a foothold.[70]

Wherever, as towards the southeastern part of the peninsula, the lagoons are less exposed to drifting sand, the vegetation generally passes through a marsh-succession and no dunes or ridges are formed. Where the sand is drifted in more abundantly, however, it tends to accumulate in the line of *Populus* and *Salix* surrounding the lagoon, thus beginning the formation of the dune. Most of the lagoons being long narrow ponds parallel to the lake-shore, the dunes formed along the line of trees arising on the banks of the lagoon also have a direction parallel to that of the lake-shore.

[70] Whitford, H. N. "The Vegetation of the Lamao Forest Reserve." *Philip. Journ. Science*, 1: 673–674, 1906.

The *Andropogon* Dune-formation.

As the cottonwoods of the *Populus* dune-formation rapidly grow in height, they constantly act as an obstacle to the drifting sand, and the ridge grows higher and higher, soon completely burying any accompanying *Salix*. The upward growth of the ridge continues usually as long as the cottonwood has an abundance of lower bushy limbs which serve to catch and retain the drifting sand. With increasing age, however, the lower limbs of the trees begin to die away and the upper growth of the dune ceases — the top of the ridge may even be blown away. Generally with the dying off of the lower limbs of the trees and the cessation of the upward growth of the dune, there appears another dune-plant, *Andropogon furcatus*, which in a measure takes the place of the lower limbs of the trees in protecting the top of the dune, or ridge, from the action of the wind. Sparingly associated with the *Andropogon* are usually a few species from the *Panicum-Artemisia* formation:

Artemisia canadensis,	*Euphorbia polygonifolia*,
Artemisia caudata,	*Lathyrus maritimus*.

The *Andropogon* dune-formation, as above described, is typically represented on the ridge commencing near the Key Post and running along the lake-shore nearly to the Light House. About a half-mile east of the Light House the lake is cutting into the shore and in places has carried away part of the ridge, thus exposing the lower buried portion of the tree-trunks to view. Where exposed the trees had been buried from nine to fourteen feet in the dune (see Plate XXXVII), and at the base of the exposure, about one and one-half feet above the water of the lake, the trunks were about two inches in diameter, increasing upwards to six to eight inches in diameter at the top of the ridge. The buried portion of the trunks had numerous dead limbs in various stages of decay and scattered among these limbs, extending nearly to the top of the ridge, were many strong roots. As mentioned in the discussion of the historical development and probable age of the peninsula, one of the undermined cottonwoods which had been cut off to free a telephone wire showed twenty-six rings of annual growth. In places this ridge is over twenty feet high and the cottonwoods are still growing vigorously, the top of the ridge being mainly held in place by the *Andropogon*.

Plate XXXVII.

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Outer *Populus* ridge east of Lighthouse, showing washing away by waves. Note adventitious roots on buried portion of tree trunks. Photographed May 8, 1906.

The *Toxicodendron* Thicket-formation.

The effect of the *Andropogon* formation upon the the habitat is, likely, the addition of considerable humus, not at the surface of the soil, but by the decay of roots and buried limbs, etc., in the lower layers. At the same time the soil is made firmer by the binding action of the roots, and the surface becomes more protected by the growth of the grass.

Under these conditions there soon appears a new set of species constituting the *Toxicodendron* thicket-formation having the following structure:

Facies. —

Toxicodendron pubescens.

Principal Species. —

Celastrus scandens, *Vitis vulpina,*
Prunus serotina, *Rubus allegheniensis,*
Prunus pennsylvanica, *Populus deltoides.*

Secondary Species. —

Rubus occidentalis, *Poa compressa,*
Fragaria virginiana, *Andropogon furcatus,*
Juniperus virginiana.

This formation is typically represented in the southeastern half of Long Ridge. The *Toxicodendron* (poison ivy) occupies almost the entire habitat by a dense thicket composed of stiffly upright, closely growing shrubs, two to five feet high. To the writer the species was quite poisonous, and the thickets impede progress considerably by being bound together by *Rubus* and *Celastrus*. *Populus deltoides* is quite abundant on Long Ridge, but the trees are dying and appear to play a relatively insignificant part in the structure of the formation and they may here be considered relicts of the preceding formation.

The *Arctostaphylos-Juniperus* Heath-formation (on ridges).

Towards the Light House the *Toxicodendron* thicket-formation gives way quite suddenly to heath, apparently exactly the same structure on the ridge as on the former sand-plain adjoining (see Plates XXVIII and XXIX). The only difference apparent is the presence on the ridge of the relict *Populus* and a greater amount of *Celastrus scandens*. There is no such broad mixed zone on Long Ridge between the *Toxico-*

dendron and the heath as there is on the sand-plain between the *Myrica* thicket and the heath. The pure heath-formation extends farther inland along Long Ridge than it does on the sand-plain, showing here its greater adaptability to positions of greater exposure.

The *Pinus Strobus* and *Quercus velutina* Forest-formations (on ridges).

The heath on Long Ridge passes into the *Pinus Strobus* forest and finally into the *Quercus velutina* forest, as does also the heath on the sand-plain. A typical example of the white pine forest occurs on the older arm of Long Ridge extending to the southwest of the Light House. The fine black oak forest at the western end of the ridge near Jetty No. 2 and on the two ridges between ridges No. 2 and No. 3, probably occupies the site (at least partially) of a former white pine forest. As has been seen, the last mentioned ridges are probably between five hundred and six hundred years old, and, from what can be deduced from known facts, it is probable that the portions of these ridges which constituted the habitat of the white pine forest have been largely washed away.

The *Prunus* Forest-formation (on ridges).

The *Toxicodendron* thicket, like the *Myrica* thicket, accumulates vegetable débris quite rapidly and with the consequent increase of humus conditions becomes suitable for other species. The succeeding formation is practically the same as that following the *Myrica* thicket; the *Prunus* forest-formation. About the only difference noted was the greater abundance of lianes; *Celastrus*, *Vitis*, *Psedera* (*Parthenocissus*) and *Smilax*, and the absence of *Alnus* and *Acer*. *Prunus virginiana* is more abundant in the early stages of the formation, and there are usually a few old cottonwoods, relicts of the earlier formations.

The *Prunus* forest-formation on ridges is relatively short lived and soon gives way to the *Quercus velutina* forest. Portions of the ridge between the Board Walk and Big and Graveyard Ponds are occupied by the *Prunus* forest, but much of this area, has evidently been burned over, and is now occupied by a secondary burn succession.

The *Quercus velutina* Forest-formation (on ridges).

The *Quercus velutina* forest-formation succeeding the *Prunus* forest is at its best on the ridges between Long and Big Chimney Ponds.

The description of this formation, as given for the forest succeeding the white pine, applies equally well for the formation as it occurs on the ridges, although the ridges attain in places to a height of nearly thirty-five feet.

The *Ammophila* Dune-formation.

For a distance of about half of a mile west of the Key Post, and again for about the same distance west of the Light House Jetty, there is a more or less broken line of *Ammophila*-dunes fringing the beach. West of the Key Post the *Ammophila* now characterizes a weak line of small dunes between the first cottonwood ridge and the beach. *Ammophila arenaria* is a stiff upright grass growing just back of drift-beaches along much of both coasts of the North Atlantic. The grass propagates itself readily in a horizontal direction by vegetative methods and is able to grow vertically for a number of feet, when continuously buried by accumulating sand. In this manner the grass and the drift-sand reciprocally operate to build up dunes, the grass acting as an obstacle around which the drifting sand accumulates. There is a limit, however, to the ability of the *Ammophila* to grow vertically with the increasing height of the dune, and at Presque Isle this limit appears to be reached at about fourteen feet above Lake Erie. The effectiveness of the grass as a dune-former is materially impaired, however, before this limit is reached, and the small dunes west of the Key Post are mainly not more than four or five feet above the surrounding sand-plain. Unlike the cottonwood ridge the *Ammophila* dune always has gentle slopes, because of the radial propagation and the small stature of the *Ammophila*.

The structure of this formation is essentially:

Facies. —

Ammophila arenaria.

Principal Species. —

Psilocybe ammophila.

Secondary Species. —

Cakile edentula, *Euphorbia polygonifolia*,
Artemisia canadensis, *Lathyrus maritima*,
Artemisia caudata, *Andropogon furcatus*,
Panicum virgatum.

During the most vigorous growth of the *Ammophila* dune there are very rarely any plants present, except the facies and the principal

species, the latter being found attached to the old dead stems and roots of the grass, and during damp periods often becoming quite abundant. In the early stages of the dune *Cakile* may be present, and in the later stages there is an increasing number of invaders from the sand-plain, especially on the lower slopes of the dune.

At Presque Isle the *Ammophila* dune, when finally surrounded by sand-plain by the general advance of the shore-line, is either quickly blown away, following the death of the grass, or else it passes quickly into an *Andropogon* dune.

As Ganong points out for the Miscou Beach,[71] the *Ammophila* starts in some accumulation of driftwood, which lying at the upper limit of the drift-beach has had time to accumulate more or lesss and. Here the *Ammophila* comes in, and, thriving best when partly covered with freshly blown sand, begins the formation of a dune. In quiet sand the grass dies in a very few years.[72]

To the west of the Light House Jetty the erosion of the beach was stopped by the building of the jetty, and the beach has since been growing lakeward, so that, instead of an abrupt cliff, there is now a gentle slope towards the water. Back of the former sea-cliff and extending up to it is the white pine forest. Outside of the forest and capping the crest of the present slope is a small area of the mixed *Myrica* heath-formation in which are a few *Prunus* and *Andropogon* dunes, and into this the pine forest is now advancing. The upper half or two-thirds of the slope is occupied by the *Ammophila* formation essentially forming a fringing dune, but on account of the proximity of the forest- and shrub-formations sand has continually filled in back of the *Ammophila* dune, as rapidly as the latter has risen above the level of the inclined plane of the slope.

Outside of the true *Ammophila* zone, and extending from there down to the *Cakile-Xanthium* formation of the drift-beach, there is a mixed formation derived from the *Ammophila*-dune and the *Panicum-Artemisia*-formations:

Andropogon furcatus, *Lathyrus maritimus*,
Artemisia canadensis, *Ammophila arenaria*,
Artemisia caudata, *Panicum virgatum*,
Populus deltoides.

[71] Ganong, W. F. *l. c.*, p. 88.

[72] Hitchcock, A. S. "Methods Used for Controlling and Reclaiming Sand-Dunes." U. S. Dept. Agr., Bur. Plant Industry, Bull. 57: 14, 1904.

Andropogon dune formation near the Key Post. In the immediate foreground note the *Lathyrus maritimus* community. Photographed September 20, 1906.

There is here the beginning of the *Populus*-ridge, a narrow lagoon having been formed and filled up, but not till after the cottonwoods had become established. The cottonwoods are now only saplings, but, present conditions continuing, there will develop in time a ridge.

The *Ammophila*-zone is now on its decline at this place, and in a few years it will likely be supplanted by the *Panicum-Artemisia*-formation. Such a result will be accelerated by the growth of the cottonwood ridge and the subsequent building up behind it of a more level plain. Associated with the *Ammophila* here are all the species mentioned for the formation in general, excepting *Cakile* and *Euphorbia*. *Andropogon*, *Artemisia* and *Lathyrus* are, perhaps, more abundant than the designation, "secondary species," would indicate.

The *Andropogon* Dune-formation.

In the discussion of the *Populus* dunes or ridges and the formations succeeding the *Populus* on them, the *Andropogon* dune-formation was discussed at some length as a component stage of a succession beginning with the *Populus* ridge or dune, but, as there are conditions under which the *Andropogon* dune-formation has no connection with the former, it has been deemed best to accord the *Andropogon* dune-formation a separate treatment.

The *Andropogon* is not a strong formation, but, aside from the important service it performs in holding together *Ammophila* or *Populus* dunes until other vegetation can obtain a foothold, there is considerable evidence that on Presque Isle *Andropogon* may cause the formation of a dune independently of other dune-forming plants (see Plate XXXVIII).

Andropogon furcatus is a bunch-grass growing in dense rounded clumps, often two feet or more in diameter, and sending up flowering stems to a height of two to three feet. Ordinarily the clumps on the sand-plain are so far apart, that, although each individual clump forms a miniature dune, there is no continuous accumulation of sand due to the joint effect of several neighboring clumps. Occasionally, however, the clumps are so close together as to have such a joint effect and a low dune is formed.

The grass apparently grows more vigorously, if somewhat elevated above the general surface of the sand-plain, and upon the new dune, or upon an old *Ammophila* or *Populus* dune, the grass-clumps are closer together, thus bringing about a greater ability on the part of the grass as a dune-former.

The *Andropogon* dune-formation of independent origin has typically the following structure :

Facies. —

Andropogon furcatus.

Principal Species. —

Artemisia canadensis, *Euphorbia polygonifolia*,
Artemisia caudata, *Lathyrus maritimus.*

Secondary Species. —

Asclepias syriaca, *Panicum virgatum*,
Panicum Scribnerianum.

The general topography of an *Andropogon* dune, either when following *Ammophila* or when originating independently, is that of a low mound or ridge with gentle slopes. Succeeding the *Andropogon* dune formation are practically the same formations as enumerated in the successions starting with the *Populus* dune or ridge, viz., either (*a*) heath, (*b*) white pine, and (*c*) black oak ; or (*a*) *Toxicodendron* thicket, (*b*) wild cherry, and (*c*) black oak.

The *Prunus pumila* Dune-formation.

The sand-cherry, *Prunus pumila*, is a low shrub forming clumps, often several yards in diameter, which are capable of stopping the drifting sand and of building up a considerable dune without the vitality of the plant being impaired. This species is quite common about certain portions of the Great Lakes, but is not common at Presque Isle. There are perhaps eight or nine small clumps of the species on the interior portion of the sand-plain and about as many more on the wind-swept narrow portion of the peninsula between the Chimney Ponds and the Head.

The dune formed by this species is usually small, but quite steep, and is more symmetrical than dunes formed by the other dune-building plants on Presque Isle. The largest *Prunus pumila* dune observed, near the remains of the Pier of 1839, is about four feet in height and eleven feet in diameter (see Plate XXXIX). No other species than the facies occurs on the *Prunus pumila* dunes, and the succession could not be definitely determined. Probably most of the dunes disappear with the death of the *Prunus*, but, possibly *Prunus virginiana* or *Toxicodendron pubescens* may sometimes act as a dune-holder and, together with *Rubus*, etc., finally pass into a thicket-formation.

ANNALS CARNEGIE MUSEUM, Vol. V. Plate XXXIX.

Prunus pumila dune on exposed sand-plain opposite Lagoon X. Miniature dune to the right formed by *Panicum virgatum*. Photographed June 10, 1906.

The Mixed *Prunus-Smilax* Dune-formation.

Along the lake-shore near Jetty No. 3, where the shore-line is receding and is faced with a sea-cliff, the wind striking the perpendicular face of the cliff is deflected upwards with sufficient force to carry sand over the brow of the cliff. There the sand is deposited in the form of a fringing ridge upon the plants constituting the lower layers of the *Quercus velutina* forest-formation. Most of these plants quickly perish under the changed conditions, but a few species survive, and these, together with certain invaders from other formations, constitute a secondary mixed shrub-formation which may be termed the Mixed *Prunus-Smilax* dune-formation.

The structure of this formation is typically as follows:

Facies. —
Prunus virginiana, *Smilax herbacea.*

Principal Species. —
Vitis vulpina, *Myrica carolinensis*,
Toxicodendron pubescens.

Secondary Species. —
Arctostaphylos Uva-Ursi, *Lonicera glaucescens*,
Solidago canadensis, *Celastrus scandens*,
Rubus allegheniensis, *Rubus occidentalis.*

The thicket produced by this formation is almost impassable, the shrubs being bound together by the luxuriant growth of lianes, particularly the *Smilax*. The oaks here are gradually dying and falling, mostly into the lake, but a few are blown backwards into the thicket and contribute to its impenetrability.

Locally, along the bay-side of the peninsula, are to be seen a few small fringing dune-formations of this character; as about three-fourths of a mile east of Big Bend, at Crystal Point, and near the U. S. L. H. Boat House.

Between the Chimney ponds and the Head there has been within comparatively recent years considerable washing away and reconstruction of the peninsula and the larger part of this area is now a sand-plain in various phases of the *Panicum-Artemisia* formation. During the various changes in the shore-line many *Populus* ridges have likely been formed, or at least begun, and subsequently wholly, or in part, again washed away. There are cottonwoods scattered about rather

promiscuously over much of this area, many of them forming dunes which appear to be fragments of former ridges. Behind the remains of the Pier of 1839 are three steep *Populus* dunes which are at least thirty feet high, and which now support the *Andropogon* dune-formation. On one trip *Morchella esculenta* was found to be quite abundant between the clumps of grass on the dunes.

THE LAGOON-MARSH-THICKET-FOREST SUCCESSION.

In the discussion of the conditions under which a *Populus* dune-formation may be instituted, it was stated that in the southeastern portion of the sand-plain, where the lagoons are less exposed to drifting sand, there is likely to be no dune-formation, but that the *Populus-Salix* formation constitutes the initial stage of a marsh-succession.

The *Populus-Salix* Formation.

Perhaps no distinction should be made between the initial stages of the *Populus* dune-succession and the *Populus-Salix* formation of the lagoon-succession. At the very first they appear to be identical, but the environment of the dune changes so rapidly with the growth of the dune, and the *Salix* plays relatively so unimportant a part in the formation, that it has seemed best to here recognize two formations. By so doing confusion of the two habitats is also avoided.

In the lagoon succession there is a remarkable gradual interpolation of successively later formations, each forming at the time of its appearance an inner ring or *zone* around the edges of the lagoon (or pond). Thus, in the structure of the lagoon-formations, *zonation*, and not *alternation*, as in the *Panicum-Artemisia* formation, is the usual method of disposition of the component parts. Some ecological workers will probably take exception to the large number of vegetational structures, which we have here given the rank of formations, but the abrupt dissimilarity in the systematic classification and in the structural adaptations of the plants of adjacent zones combine to make the ecotones very distinct, indeed, and, considering the differences in the ecological conditions of the habitat, there appear to be good reasons for the recognition of a considerable number of zoned formations.

The accumulation of drifting sand about the banks of a lagoon is usually so rapid that in a few years the surface of the soil in the *Populus-Salix* zone has been brought up to the general level of the surrounding sand-plain, but the general advance of the shore-line lakeward leaves the lagoon farther and farther inland, and, at the same time, the vegetation increases immediately around the lagoon, so that decreasing amounts of sand will be drifted into the lagoon and into the innermost zones of vegetation. From this it follows, that, after the *Populus-Salix* formation, each succeeding inner zone will have been built up of less rapidly accumulated sand, and, as farther inland the drifting sand is composed of finer particles, the zoned habitats are thus characterized by successively finer-grained, more compact soils, and in a general way each has taken a longer time in its building. Furthermore, the accumulation of organic matter, humus, becomes relatively a more important factor in the edaphic conditions of each successive habitat.

Contemporaneous with the initial stages of the *Populus-Salix* formation there is a submerged formation in its initial stages in the waters of the lagoon, and, as the ecological relations of the land and water formations of the lagoons are very intimate, it has seemed best to take up their consideration together. The different stages in the succession will be considered, as they are exemplified in the different lagoons and ponds, in the order of development of the successive formations.

Stage A. — Lagoon Aa (see Map).

(*a*) *Potamogeton* formation,
(*b*) *Populus-Salix* formation.

The *Potamogeton* Formation.

During the first few years of the existence of the lagoon, and contemporaneously with the beginning of the *Populus-Smilax* formation, the lagoon is in many respects merely a portion of the lake, cut off by a sand-bar, and of the same character as the lake itself; but, considered as a habitat, the two are quite distinct. The waters of the lagoon, not being mingled with the uniformly cool currents of the lake, but being comparatively shallow and stationary, are subjected to greater variations in temperature than are the waters of the lake. During the growing season the water of the lagoon presents an excess of heat above the waters of the lake; during hot midsummer days temperatures above 90° Fahrenheit were noted in some of the more open lagoons south of the Fog Whistle, while at the same time the lake along the beach-line had a temperature of about 70° Fahr.

Another difference between the two habitats is to be noted in the constant clearness and transparency of the waters of the lagoons, whereas the lake is often distinctly turbid.

To briefly sum up the differences between the environment afforded by the lagoons and the lake; the former (*a*) is warmer during the growing season, but (*b*) has a greater variation of temperature, (*c*) is free from currents and mechanically violent waves, and (*d*) has a greater amount of insolation below the surface.

The structure of the *Potamogeton* formation is typically:

Facies. —

Potamogeton pectinatus.

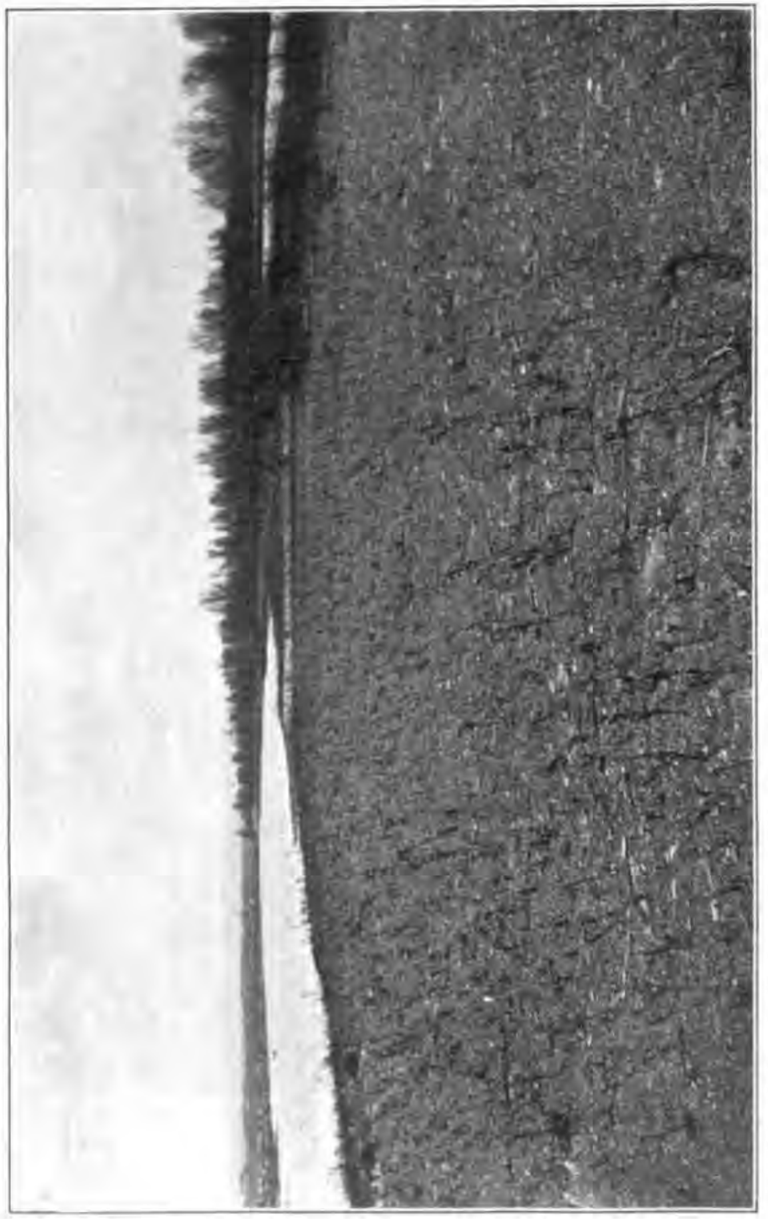
Principal Species. —

Potamogeton pusillus, *Vallisneria spiralis.*

Fruiting specimens of *Potamogeton pectinatus* appear very early in the life of the lagoon, and perhaps may represent simply a continuation of a formation of the lake itself. Probably many of the plants of the lagoon are derived directly from the lake by the separation of the lagoon from it. Other plants were likely derived from disseminules which were buried by wave-action in the sand forming the bottom of the lagoon. The facies of the formation appears mainly in the deeper part of the lagoon where the depth is three feet or more. The principal species, however, are quite abundant in the shallower water, even where not over eight or nine inches deep. In Lagoon Aa the plants were spreading rapidly by rhizomes, which were buried about an inch in the sand, and which were sending up rosettes at intervals of a few inches. The rosettes in the shallow water near the shore were probably buried by indrifting sand before they attained maturity.

The *Populus-Salix* Formation.

During periods of wet weather or of high water in the lake the water in the lagoons quite frequently rises sufficiently to inundate the zone of cottonwood and willow seedlings which at this stage constitutes the *Populus-Salix* formation. Around Lagoon Aa the ecesis of these two species was accomplished during the summer following the segregation of the lagoon from the lake. In places on the west side of the lagoon the formation is about thirty feet wide and consists almost entirely of seedlings in their fourth year in 1906 (see Plate XL). The indrifting



Between C and Aa, looking south. Wide Zone of the *Populus Salix* formation, cottonwoods four years old. The *Juncus-Eleocharis* formation is coming in along the water's edge. Photographed May 8, 1906.

of sand was mainly from the westward so that the formation as a whole is considerably narrower on the east side of the lagoon (see Plate XXVI).

The habitat may be said to be dissophytic. During the most xerophytic periods the sand even at its surface is generally distinctly dark-colored on account of the water it contains. The water-table is so near the surface that even in the loose sand capillarity suffices to keep the water-content of even the surface very high. However, with the drifting in of sand the zone is gradually elevated and becomes dryer at the surface, while a zone of wet sand is simultaneously formed inside the first zone, thus providing a habitat for a succeeding formation. During the year 1906 no little seedling cottonwoods or willows could be found in the innermost zone of wet sand around Lagoon Aa, and thus the *Populus Salix* formation has here reached its territorial limits for this lagoon.

In the manner indicated, there is brought about a remarkable regularity in age and size among the plants constituting the *Populus-Salix* zone, so that the formation often appears like a planted hedge surrounding the lagoon. All over the sand-plain there are long regular lines of cottonwoods indicating the shore of a former lagoon, long since filled up with sand. These vegetational structures are to be regarded, not as component parts of the *Panicum-Artemisia* formation, but rather as "relicts" of a *Populus-Salix* formation, although they may figure quite prominently in the general landscape.

The typical structure of the *Populus-Salix* formation is:

Facies. —

Populus deltoides, *Salix syrticola*.

Secondary Species. —

Artemisia caudata, *Artemisia canadensis*,
Onagra biennis, *Aster ericoides*,
Panicum virgatum.

During the first few years of this formation there are practically no species present other than the facies, but, as the surface-level becomes more elevated, approaching more closely the conditions of the sand-plain, there are a few invaders from the latter habitat, ranking, however, merely as secondary species.

Stage B. — Lagoons C and G.

(*a*) The *Potamogeton* formation,
(*b*) The *Juncus-Eleocharis* formation,
(*c*) The *Populus-Salix* formation.

Around Lagoons C and G (see map) the *Potamogeton* and *Populus-Salix* formations are older and somewhat more mature than around Lagoon Aa, although otherwise essentially the same. Inside the *Populus-Salix* zone, however, there is a new zone, which from its facies may be termed the *Juncus-Eleocharis* formation (see Plate XLI). This formation is also to be seen at the extreme northern end of Lagoon Aa, where encroachment of the sand upon the water is proceeding more rapidly.

The *Juncus-Eleocharis* Formation.

The hedge of small cottonwoods and willows constituting the *Populus-Salix* formation serves as a partial protection against the drifting sand and the habitat (*edaphic*) of the inner zone is thus formed of a more compact soil of a finer texture, which is not easily worked over by the little waves of the lagoon, and thus does not afford suitable conditions for the burial and ecesis of *Populus* or *Salix*. However, the zone is soon occupied by a formation of rush-like and sedge-like plants, mostly spreading about in the wet sand by means of rhizomes.

The structure of the formation is:

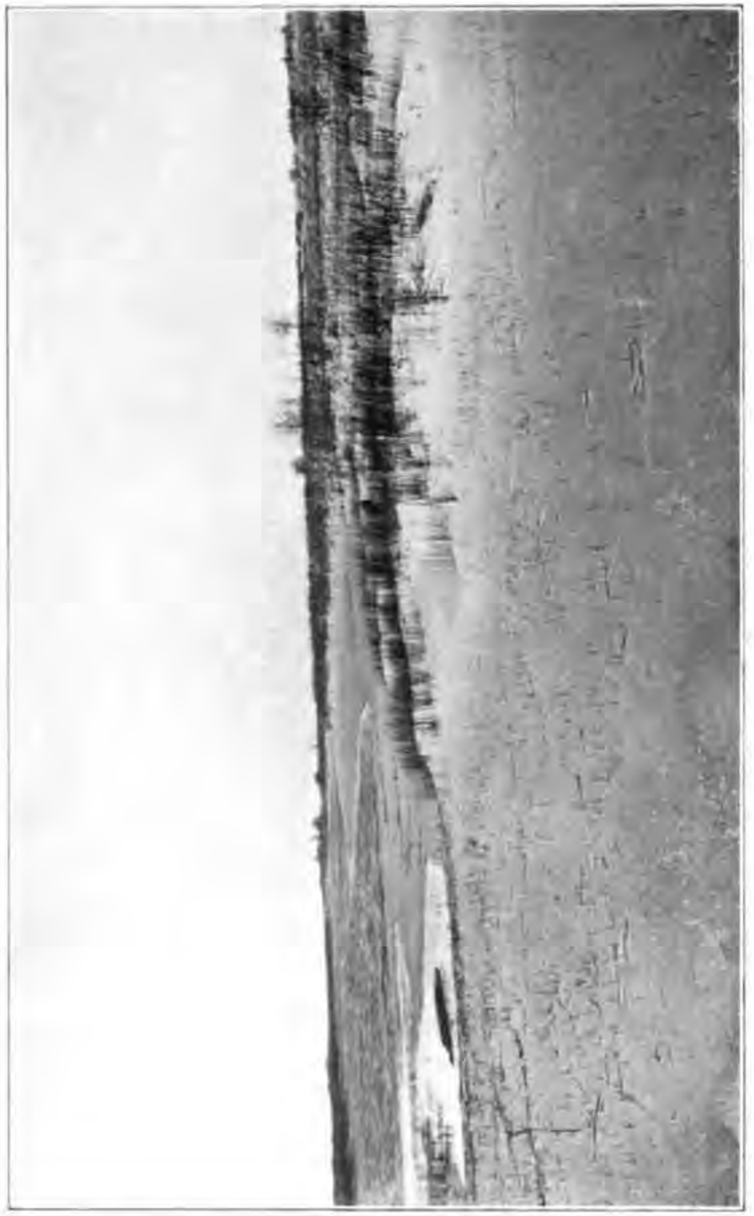
Facies. —
Juncus balticus littoralis, *Eleocharis acuminatus*,
Eleocharis obtusa.

Principal Species. —
Triglochin palustris, *Carex Oederi pumila*.

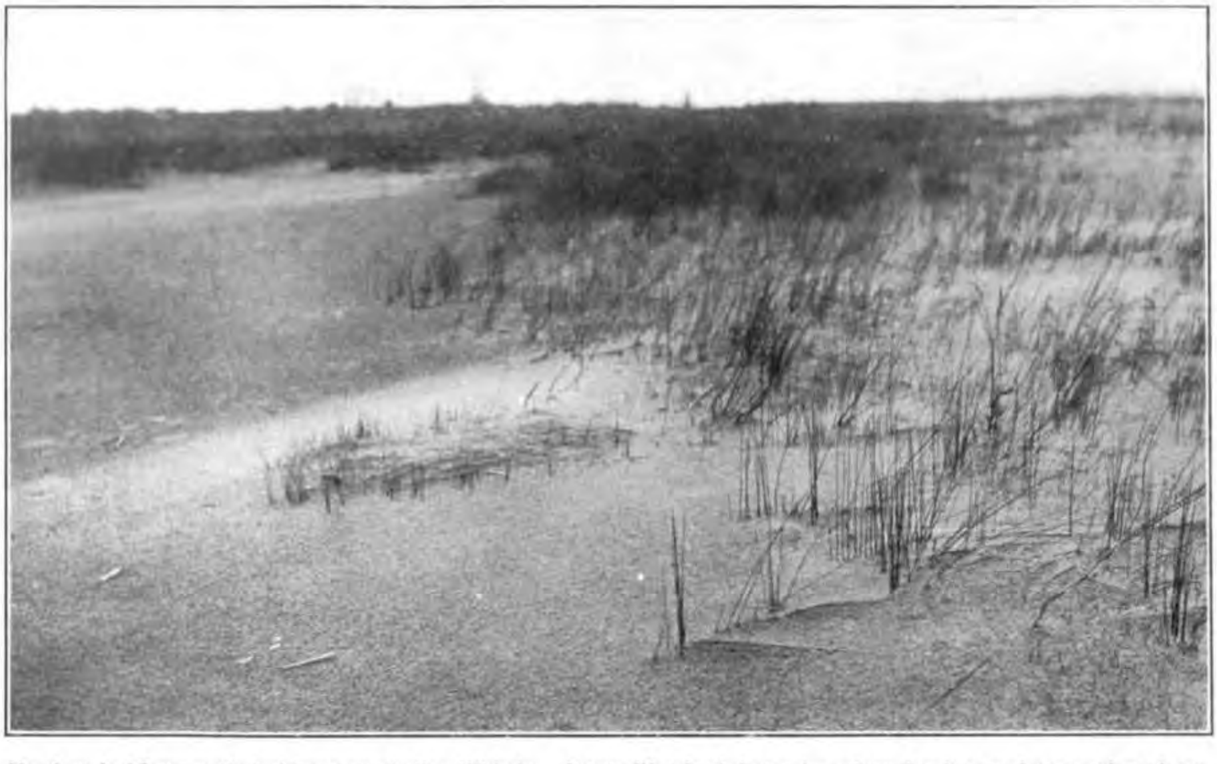
Secondary Species. —
Cyperus flavescens.

Each of the two species of *Eleocharis*, by aggregation, usually form closed circular mats (families and communities), into which no other species of the local flora appears able to penetrate and which often accumulate the sand quite rapidly, appearing then in miniature dunes two or three inches above the surrounding sand, these patches increasing in area radially by the further growth of the rhizomes of the *Eleocharis* (see Plate XLII).

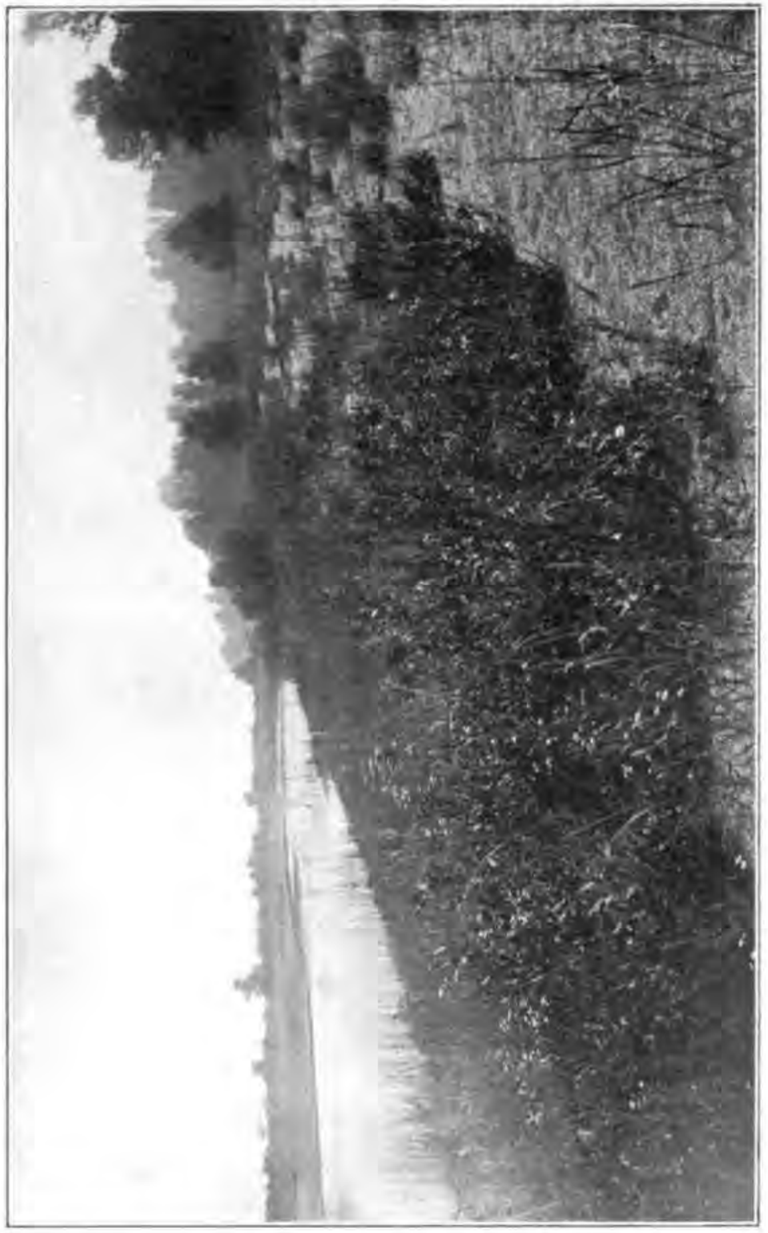
ANNALS CARNEGIE MUSEUM, Vol. V. Plate XLI.



Southwest shore of Lagoon G near Key Post. *Scirpus* is being buried by accumulating sand, but the *Juncus-Eleocharis* formation is rapidly advancing and building up the shore. Photographed May 8, 1906.



North end of Lagoon C, looking towards Fog Whistle. *Juncus-Eleocharis* formation advancing into moister portion of rapidly accumulating sand. Note mound of *Eleocharis* in center of picture. Photographed May 15, 1905.



Lagoon C, looking south along west bank. Stage D of the Lagoon Succession. *Populus Salix* zone in distance at edge of sand-plain. Next lower is *Myrica-Salix* zone, in *Aster ericoides* aspect; *Sabbatia-Linum* and *Typha-Scirpus* zones. Photographed September 20, 1906.

The *Juncus* spreads rapidly along the wet banks and out under the water by means of its strong slender rhizomes. Sometimes the plant forms practically closed associations, but, usually, the plants are more or less scattered in lines indicating the direction of growth of the rhizome. When the sandy shore is advancing rapidly upon the water of the lagoon the direction of growth of the rhizomes is very strikingly inward, towards the water-line.

Triglochin palustris appears scattered here and there in the *Juncus-Eleocharis* zone, sometimes becoming so prominent as perhaps to merit a higher rank than principal species. It never penetrates the closed *Eleocharis* consocies, but is sometimes mixed with the *Juncus balticus littoralis*.

The formation, as may be seen from the above statements, is composed of alternating consocies which may be termed:

The *Juncus balticus littoralis* consocies,

The *Eleocharis acuminatus* consocies,

The *Eleocharis obtusa* consocies.

In the upper, dryer part of the zone, practically marking the ecotone between the *Populus-Salix* and the *Juncus-Eleocharis* formations, is the *Carex-Oederi pumila* society, which characterizes very distinctly an early summer aspect. The same area is occupied later in the season by the less abundant *Cyperus flavescens*.

Stage C. — Lagoons C, D, and part of G.

(*a*) *Potamogeton* formation,
(*b*) *Typha-Scirpus* formation,
(*c*) *Sabbatia Linum* formation,
(*d*) *Populus-Salix* formation.

Towards the ends of Lagoon G, which had been quite largely filled with sand during 1905 and 1906, there are patches of two formations not found along the sides of the lagoon, but which can be seen to be replacing the *Juncus-Eleocharis* formation as well as occupying the previously occupied shallower parts of the lagoon. These formations are to be seen farther advanced and more typical in Lagoons C and D (see Plate XLIII).

Taking the formations in regular order from the center of the lagoons outward, the formations of Stage C may be described as follows:

The *Potamogeton* Formation.

This formation has undergone no change from its structure in the earlier stages except that *Potamogeton pectinatus* is more abundant and is more frequently found fruiting than was the case in the earlier stages. No rosettes are to be seen in shallower water, as in Lagoon Aa, as this area has been taken over by the *Typha-Scirpus* formation.

The *Typha-Scirpus* Formation.

The structure of the formation is, typically:

Facies. —

Scirpus Americanus, *Scirpus validus*,
Typha latifolia.

Principal Species. —

Eleocharis olivacea, *Sparganium eurycarpum*.

Secondary Species. —

Juncus balticus littoralis, *Utricularia cornuta*,
Eleocharis obtusa, *Nostoc* sp.

This formation has its outer limit in about one and one-half feet of water and from here it extends back on the bank to a height of about eight inches above the water level. The habitat might thus be said to be amphibious, but to the plants it is uniform in that the top of the stem is in the air and the roots are in a saturated soil. The *Juncus-Eleocharis* formation probably added some humus and thus increased the capillary power of the soil. The soil is here made dark with moisture back to a height of about a foot above the water-level of the lagoon. The lower part of the *Juncus-Eleocharis* formation is supplanted by the *Typha-Scirpus* formation; in places almost the entire habitat has been so occupied.

The *Typha latifolia* consocies appears in the deeper, submerged portion of the habitat, and alternates with the *Scirpus validus* consocies. The *Scirpus americanus* consocies occupies by far the most important place in the formation, but it exhibits more or less zonation with the *Scirpus validus* consocies, which usually occupies the outer, more deeply submerged zone. Excepting *Sparganium*, which occurs in the *Typha latifolia* consocies, the principal and secondary species of the formation occupy the bank in the *Scirpus americanus* consocies. In places the soil around the bases of the stems of the *Scirpus* is almost completely covered with little pellets of a species of *Nostoc*.

The *Sabbatia-Linum* Formation.

Supplanting the upper part of the *Juncus-Eleocharis* formation, and, more especially, the *Carex Oederi pumila* society, is a formation, which, unlike any of the formations before described, consists mainly of rosette-forming biennials and perennials.

The structure of the formation is, typically:

Facies. —

Sabbatia angularis, *Linum medium*.

Principal Species. —

Gerardia paupercula, *Ibidium incurvum*,
Lobelia Kalmii.

Secondary Species. —

Utricularia cornuta, *Juncus tenuis*,
Eleocharis obtusa, *Scleria verticillata*,
Juncus canadensis, *Campanula aparinoides*,
Nostoc sp., *Psilocybe ammophila*.

This formation is practically a closed one, but aside from several quite distinct aspects there is practically no grouping, the species being indiscriminately intermingled within the limits of the habitat. This formation more proportionally than any other formation on the peninsula is marked by the variety and abundance of its floral display, the different species alternating with each other in their periods of bloom to such an extent that flowers are in evidence almost continuously from early summer till late fall.

Some of the more important species characterizing corresponding aspects are:

Sabbatia angularis, *Linum medium*,
Lobelia Kalmii, *Gerardia paupercula*,
Ibidium incurvum *Utricularia cornuta*.

The *Populus-Salix* Formation.

This formation in the stage under discussion usually occupies a habitat now completely on a level with the surrounding sand-plain, and indeed very little different from that habitat in most particulars. Around Lagoon D the cottonwoods have attained to a diameter of three and one-half inches and are beginning to lose some of the lower branches. The willows are beginning to die out also, so that the

hedge-like appearance of the formation is disappearing, and the environment is becoming changed, because there is a much greater illumination of the soil about the base of the trees.

Stage D. — Lagoons C, D, and end of G (see Plate XLIV).

(*a*) *Potamogeton* Formation,
(*b*) *Typha-Scirpus* Formation,
(*c*) *Sabbatia-Linum* Formation,
(*d*) *Myrica-Salix* Formation,
(*e*) *Populus-Salix* Formation.

Stage D presents most of the formations in essentially the same condition as they were described for Stage C, but in the more advanced portions of the vegetation of the banks around the lagoons mentioned in the heading there appears a new formation, so that it seems best to indicate a stage of the succession coincident with the entrance of the new formation, which may be called from its facies the *Myrica-Salix* thicket-formation.

The *Myrica-Salix* Thicket-formation.

With the further advance of the sand upon the lagoon and the consequent widening of the bank inside of the *Populus-Salix* zone, there is a forward movement of the *Sabbatia-Linum* formation, at the same time that its outer border is being invaded and taken over by the *Myrica-Salix* formation, the latter thus forming a zone between the *Sabbatia-Linum* formation and the *Populus-Salix* formation.

The *Myrica-Salix* formation is a typical shrub association and is characterized by the wax myrtle, *Myrica carolinensis*, and the two willows, *Salix discolor* and *Salix cordata*. The ecotone between the two willows of this formation and the *Salix syrticola* of the *Populus-Salix* formation is very striking, but when the ecological conditions obtaining in the two habitats at the time of ecesis of the respective formations are considered, the apparent similarity of conditions is not so great. The one willow accomplished ecesis under practically sand-bar conditions, while the other two found suitable conditions in the more compact, damp, humus-containing soil of the rosette zone (*Sabbatia-Linum* formation).

The structure of the *Myrica-Salix* formation is thus:

Facies. —

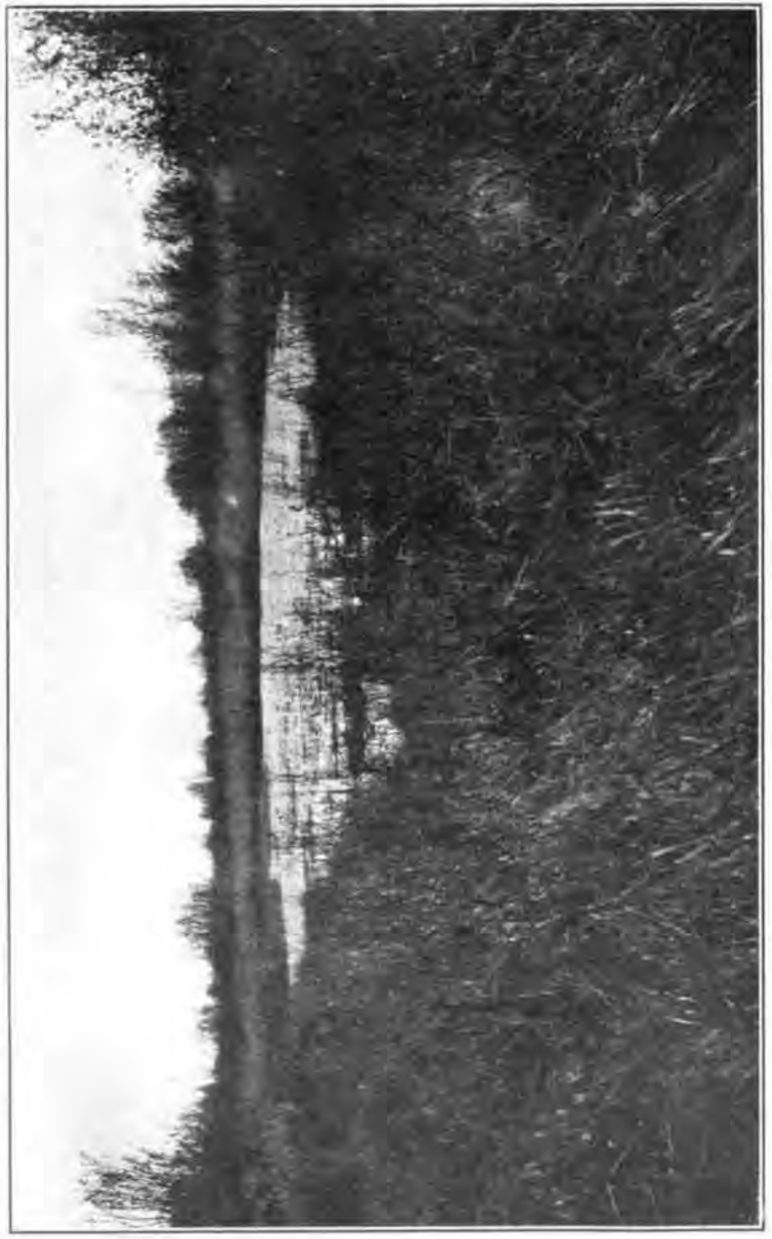
Myrica carolinensis, *Salix cordata*,

ANNALS CARNEGIE MUSEUM, Vol V. Plate XLIV.

West bank of Lagoon D, looking south. Stage C of Lagoon Succession showing *Myrica-Salix* formation displacing *Scirpus* and *Sabbatia-Linum* formations; between this and the sand-plain is the *Populus-Salix* zone. Photographed May 8, 1906.

Lagoon D, looking east across the depression running towards the Fog Whistle. Shows a mature *Scirpus americanus* consocies of the *Typha-Scirpus* formation. Photographed September 20, 1906.

Lagoon E, looking north. In the foreground is expanse of *Cladium* consocies of the *Cladium-Calamagrostis* formation. Next is *Typha-Scirpus* formation, *Typha* to right. *Nymphæa* in center of Lagoon. Photographed May 8, 1906.



Lagoon Ea, looking north. Stage E of the Lagoon Succession. Beginning in the center are: *Potamogeton*, *Nymphæa*, *Scirpus-Typha*, *Cladium-Calamagrostis* (in middle foreground), *Myrica-Salix* and *Populus-Salix* zoned formations. Photographed May 8, 1906.

Salix discolor.

Principal Species. —
Solidago canadensis, *Aster ericoides.*
Secondary Species. —
Scleria verticillata, *Linum medium,*
Nostoc sp.

The *Solidago canadensis* aspect is very conspicuous in the fall, just as in the *Myrica* thicket-formation on the sand-plain. There is much similarity, in fact, between these two thicket-formations, but in their manner of origin they are quite distinct, and the willows do not enter into the structure of the thicket on the sand-plain.

The beginning of the *Myrica-Salix* thicket-formation is best exemplified in the "swale" which marks the former extent of a lagoon, of which Lagoon D is the remnant (see Plate XLV). This swampy area averages about three rods in width and extends from Lagoon D towards the Fog Whistle for a distance of about one-eighth of a mile. The area is but a little lower than the sand-plain adjacent and the habitat now affords a beautiful example of a mature *Scirpus americanus* consocies of the *Typha-Scirpus* formation. This formation, however, is bordered by a *Sabbatia-Linum* zone, which is being rapidly supplanted by the *Myrica-Salix* zone. The pioneers of the shrub zone are *Myrica*, while the two willows and the *Aster* are just appearing.

Stage E. — Lagoons E, Ea, F, and Fa.
(*a*) *Potamogeton* Formation,
(*b*) *Nymphæa* Formation,
(*c*) *Scirpus-Typha* Formation,
(*d*) *Cladium-Calamagrostis* Formation,
(*e*) *Myrica-Salix* Formation,
(*f*) *Populus-Salix* Formation.

Stage E is exemplified around Lagoons E, F, and Fa, which were apparently segregated from the lake at about the same time, being nearly in line with each other abreast and being very similar in their vegetation (see Plates XLVI and XLVII).

The *Potamogeton* Formation.

The *Potamogeton* formation here is becoming somewhat more restricted but at the same time it is better developed and is more clearly defined from the zones surrounding it. It occupies the deeper water of the lagoons, shallowing out to a depth of about five feet.

The structure of the *Potamogeton* formation in this stage is:

Facies. —

Potamogeton pectinatus.

Principal Species. —

Potamogeton natans, *Naias flexilis,*
Potamogeton lonchitis, *Utricularia vulgaris.*

Secondary Species. —

Vallisneria spiralis, *Philotria canadensis.*

The *Nymphæa* Formation.

The *Nymphæa* formation occupies a zone outside of the *Potamogeton* formation, in water from two to five feet in depth. It is not yet well developed in this stage, but it is invading all three of the lagoons associated with this stage.

The structure of the formation as here developed is:

Facies. —

Nymphæa advena.

Principal Species. —

Pontederia cordata.

The *Scirpus-Typha* Formation.

The *Scirpus-Typha* formation in Stage E extends from a few inches above the water-level on the wet bank to a depth of about fourteen inches below the water-level. Its structure is mainly the same as in Stage D, but the *Sabbatia-Linum* formation surrounding it has been supplanted by a formation, which, when once invasion has begun, rapidly gains entire possession of the habitat, and, being very stable, is able to retain possession for a comparatively long period.

The *Cladium-Calamagrostis* Formation.

The structure of this formation is here as follows:

Facies. —

Cladium mariscoides, *Calamagrostis canadensis.*

Principal Species. —

Aster ericoides.

Secondary Species. —

Asclepias incarnata, *Hypericum boreale,*
Dryopteris thelypteris, *Cyperus flavescens,*
Equisetum hyemale.

This formation consists so largely of the grass-like facies that it conveys at once the impression of a wet meadow. The structure of the formation is simple, but there is a very distinct succession of the two facies. The *Cladium mariscoides* consocies always appears first, and usually it has the *Sabbatia-Linum* formation suppressed before the appearance of *Calamagrostis canadensis.* In older structures the *Cladium* has entirely disappeared, leaving the *Calamagrostis canadensis* consocies in undisputed possession. The later appearance of the *Calamagrostis* depends probably upon the accumulation of certain amounts of humus in the soil.

Usually contemporaneously with the appearance of the *Calamagrostis* there appears in the upper portion of the consocies a zone characterized during the autumn aspect by *Aster ericoides,* thus constituting an *Aster ericoides* society. Often associated with the *Aster* is *Equisetum hyemale.* In places the *Aster ericoides* society becomes very prominent and almost entirely dominates an upper zone of the formation.

Of the other secondary species mentioned in connection with the *Cladium-Calamagrostis* formation the *Cyperus* is more largely associated with the *Cladium mariscoides* consocies, while the *Dryopteris, Asclepias,* and *Hypericum* are found with the *Calamagrostis.*

This formation, essentially a wet meadow, which is rarely or never submerged, occupies comparatively large areas around Lagoons E, F, and Fa, and in the older portions of the peninsula is represented by the *Calamagrostis canadensis* consocies, as around Lagoon B, and in the three marshy areas between B and Horse-shoe Pond. Lagoon Y is now essentially such a wet meadow with, however, some *Phragmites* in the moister portion and a border of shrubs on the landward side.

The *Myrica-Salix* Formation.

The *Myrica-Salix* zone of shrubs has at this stage attained its greatest development, and will soon be supplanted by another shrub-formation characterized by taller and more rapidly growing species. This succession is apparently made possible by the accumulation of humus in the soil, and perhaps also by the protection offered the young seedlings by the brushy growth of *Myrica.* The structure of the *Myrica-Salix* formation at its culmination is not essentially different from its structure as described for Stage D, excepting that invasion by the next formation has begun, as is evident from the presence here of *Alnus incana* and *Rhus typhina.*

The *Populus-Salix* Formation.

This formation, at the stage under discussion, shows but little change from its structure in Stage D, other than in the growth of the cottonwood trees. The willow has almost entirely died out and a few of the sand-plain species are beginning to crowd in around the bases of the cottonwoods.

Stage F. — Lagoon Eb.

The middle one of the three marshy areas between Horse-shoe Pond and Lagoon B presents an example of a stage in the succession somewhat further advanced than in Lagoon E, and there are quite a number of changes to be noted in the different formations, as well as the appearance of one new formation.

The structure of the vegetation of this marsh, as far as it is at present represented, is as follows:

(*a*) *Scirpus-Typha* Formation,
(*b*) *Cladium-Calamagrostis* Formation,
(*c*) *Rhus-Alnus* Formation,
(*d*) *Populus-Salix* Formation.

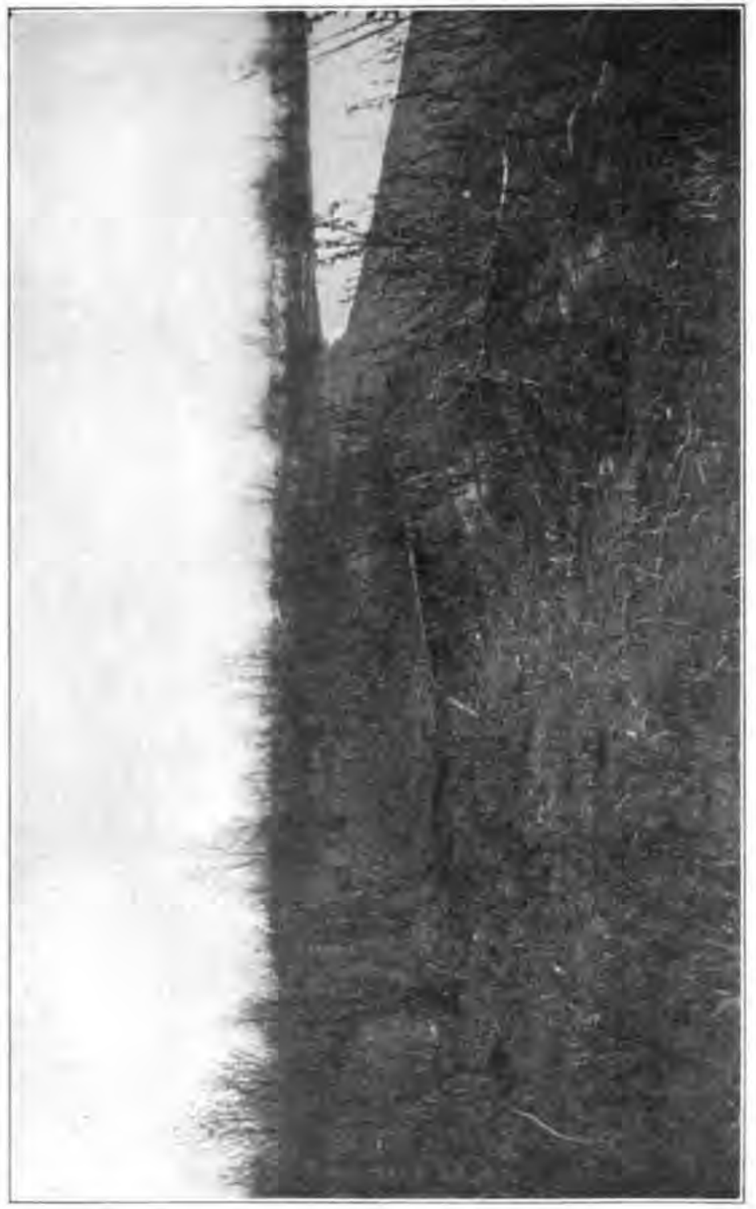
The habitat of this series has been derived from a long narrow lagoon, running parallel to the shore of the northwest end of Horse-shoe Pond, from which this area as well as the two adjacent marshy areas were derived, formerly having been lagoons (see Plate XLVIII). In the middle one of these areas the lagoon has been filled to such an extent that the lowest portion is inundated only at times of heavy rainfall. The vegetational zones have closed in on the lagoon, so that the deeper central portion is now occupied by the *Scirpus-Typha* formation.

The *Scirpus-Typha* Formation.

This formation is here in a rather advanced stage, which is mainly marked by the predominance of the *Typha latifolia* consocies. *Scirpus americana* is present, but is rather scarce and is not in a vigorous condition. Of the three consocies of the formation the *Typha latifolia* consocies is evidently more partial to a humus soil, while *Scirpus americana* and *Scirpus validus* reach their best development in almost pure sand. Drainage conditions perhaps enter into the problem to a certain extent.

Secondary species are here more abundant than in previous stages and are as follows:

ANNALS CARNEGIE MUSEUM, Vol. V. Plate XLVIII.



North end of Horse Shoe Pond, showing regular lines of willows and cottonwoods formed with the cutting off and filling of narrow lagoons. The depression in the middle of the picture is now occupied by an impure *Sabbatia-Linum* formation. Photographed May 8, 1906.

Hypericum boreale, *Hypericum canadense*,
Scirpus cyperinus, *Juncus canadensis*,
Eleocharis quadrangulata, *Pontederia cordata*,
Nostoc sp.

Muskrats have formed many mounds and run-ways in this area, and in so doing have exposed to view the sand, upon which there has been a return of *Eleocharis acicularis* and a new invader from the shrub-zone, *Salix lucida*.

The *Cladium-Calamagrostis* Formation.

This formation is being here invaded very rapidly by the shrub-zone around most of the marsh, the pioneer *Myrica* clumps (families and communities in many cases) being scattered about here and there in advance of the main shrub-zone. *Salix cordata* here advances by even longer leaps than does the *Myrica*, but it does not form such compact clumps.

The structure of the formation at this stage is as follows:

Facies. —
Calamagrostis canadensis (predominant),
Cladium mariscoides (inconspicuous).

Principal Species. —
Dryopteris thelypteris, *Triadenum virginicum*,
Aster ericoides.

Secondary Species. —
Onoclea sensibilis.

Where the *Cladium-Calamagrostis* zone is wider, or where for some reason the shrub-zone advances more slowly, the meadow-formation develops a structure consisting of what may be called the *Fragaria virginiana* society, which is followed later in the season by the *Aster ericoides* society, as described under Stage E. The structure of the *Fragaria virginiana* society is as follows:

Principal Species. —
Fragaria virginiana.

Secondary Species. —
Dasystoma virginica, *Lactuca canadensis*,
Solidago nemoralis, *Solidago canadensis*,
Aster ericoides, *Eupatorium perfoliatum*,
Sorghastrum nutans, *Panicum virgatum*,
Cladonia sp.

This society consists in part of species, which are representative of the sand-plain, and this fact in connection with the sandy condition of the soil, which is in places comparatively free from humus, indicates a close similarity between this habitat and portions of the sand-plain. However there are invading groups of *Myrica* and scattering individuals of *Salix cordata*, so that a final occupation of the habitat by the shrub-formation is indicated.

The *Compositæ*, mentioned above as secondary species in the *Fragaria virginiana* society, reach their most conspicuous development only in the autumnal aspect, when that society is overshadowed by the *Aster ericoides* society.

The *Rhus-Alnus* Formation.

The *Myrica-Salix* thicket, as is evident at this stage, and still more evident in the next stage of the formation, is supplanted eventually by a shrub-formation, which is in reality rather intermediate between thicket and forest. The formation is mainly composed of shrubs and small trees and its vegetational structure is as follows :

Facies. —

Alnus incana,	*Rhus typhina*.

Principal Species. —

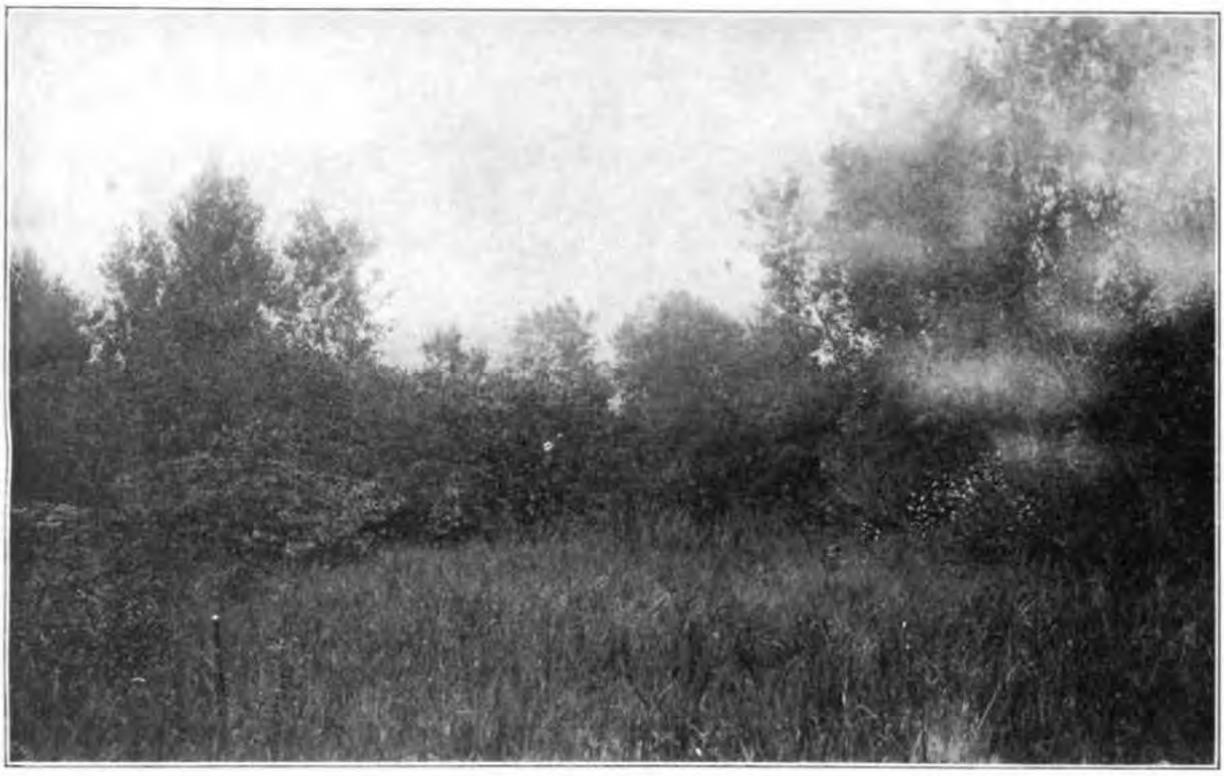
Vitis vulpina,	*Cornus stolonifera*,
Solidago canadensis,	*Cornus amomum*.

Secondary Species. —

Salix cordata,	*Salix discolor*,
Salix nigra,	*Fragaria virginiana*,
Rubus allegheniensis,	*Acer saccharinum*,
Dryopteris thelypteris,	*Toxicodendron pubescens*.

During the earlier stages of this formation, and before the taller growing species have become large enough to shut out the light, the principal and secondary species flourish, but with the maturity of the facies and the consequent development of a more or less dense but low "forest cover,"[73] there is a corresponding disappearance or rearrangement of these smaller species. When typically well developed the formation consists of a dense growth of either the *Alnus incana* consocies or the *Rhus typhina* consocies, or a consocies composed of a mixture of the two facies, the whole forming a zone just inside of the zone of cottonwoods.

[73] Pinchot, Gifford. "A Primer of Forestry." Part I.—The Forest. U. S. Dept. Agriculture, Div. Forestry, Bull. 24 : 11. 1900.



Wet meadow between Horse-Shoe Pond and B. Stage G of the Lagoon Succession. *Calamagrostis canadensis* consocies with a clump of relict *Typha* in distance. *Rhus-Alnus* zone encroaching. The larger trees are cottonwoods of the old *Populus-Salix* formation. Rising fog obscures on right. Photographed September 20, 1906.

Plate L.

Wet meadow between Horse-Shoe Pond and B. Stage G of the Lagoon Succession. The *Rhus-Alnus* shrub formation rapidly occupying the *Calamagrostis* meadow. Foremost invaders are *Alnus* at the left and *Myrica* at the right. *Solidago* and *Eupatorium* in middle distance. Photographed September 20, 1906.

Besides this alternation of consocies the formation also exhibits layering and zonation within itself.

On the outside of the mature *Rhus-Alnus* zone, and often leading out into the *Populus* zone, there is usually a low shrub zone characterized by *Myrica carolinensis*, *Rubus allegheniensis*, and *Solidago canadensis*, the whole often being overgrown with *Vitis vulpina*. On the inside of the tall *Rhus-Alnus* zone there is again a secondary zone, which is often rather complex in structure. Principal among its species, besides young plants of the facies, are *Myrica*, *Solidago canadensis*, *Cornus stolonifera*, *Cornus amomum*, *Salix discolor*, and *Salix nigra*.

Where the facies forms a closed structure, the forest-cover is so complete, that none of the plants the disseminules of which reach this location, aside from certain fleshy fungi, *Russula emetica*, *Lactarius piperatus*, *Boletus* sp., etc., which form a transitory ground layer, are able to accomplish ecesis, and the dark pper soil is in places entirely devoid of vegetation. With the death of some of the facies, or where the forest-cover is not so complete, there is a rather weak secondary layer consisting usually of the species which constitute the inner secondary zone.

Stage G. — Lagoon B, Eb, and Marsh 3.[74]

In Marsh 3 (see Plates XLIX and L) the central portion of the lagoon is now entirely filled up and has progressed to the *Calamagrostis canadensis* consocies of the *Cladium-Calamagrostis* formation. There is much *Dryopteris thelypteris* and some *Scirpus cyperinus*, and in a depression at one end there is a small clump of *Typha latifolia*, a relict of a former consocies. Several of the Compositæ of the *Cladium-Calamagrostis* formation are also present. The shrub-zone is encroaching on the meadow very rapidly, and at one end of the meadow there is now only a narrow lane between the shrub-borders, so nearly have they approached each other. Some of the last meadow species to disappear among the advancing plants of the shrub-formation are *Eupatorium perfoliatum* and *Scirpus cyperinus*. *Solidago canadensis* increases in abundance among the smaller shrubs, especially the *Myrica* of the inner secondary zone of the *Rhus-Alnus* formation.

Lagoon Eb, a small oblong pool near Long Ridge, now about thirty feet long, presents the following rather fragmentary structure:

[74] The three small marshes immediately north of Horse-shoe Pond are spoken of, consecutively from north to south, as Numbers 1, 2, and 3.

(*a*) *Nymphæa* formation, which here consists mainly of *Nymphæa advena* with some *Alisma Plantago* and *Pontederia cordata*, together with remnants of the *Potamogeton* formation — *Potamogeton pectinatus*, *Naias flexilis*, and some *Myriophyllum spicatum*.

(*b*) The *Scirpus-Typha* formation, which is here represented by *Typha latifolia* with some *Scirpus americanus* and *Dulichium arundinaceum*, and around the outer border a few plants of *Carex gynandra*.

(*c*) The *Calamagrosis canadensis* consocies of the *Cladium-Calamagrostis* formation with a few relict plants of *Cladium*.

(*d*) The *Rhus-Alnus* formation, in which *Alnus* has become mature and dominant, having associated with it some *Cornus amomum*, *Salix discolor*, and around the outside a secondary zone of *Myrica*.

Another little pool near the south end of Long Ridge has about the same vegetation, except that the *Potamogeton* formation is still intact in a small patch. The structure is essentially thus:

(*a*) *Potamogeton* formation,
(*b*) *Nymphæa* formation,
(*c*) *Typha-Scirpus* formation, represented only by the *Typha latifolia* consocies, and having around its outer border a distinct zone of *Carex gynandra*.
(*d*) The *Rhus-Alnus* formation, which has completely conquered the *Cladium-Calamagrostis* formation, and consists here mainly of *Alnus incana* and *Cornus stolonifera*.
(*e*) There is the beginning in the older part of the shrub-zone of a forest-formation, as is evidenced by the appearance of *Acer saccharinum* and *Prunus serotina*.

At Lagoon B the following structure is evident:

(*a*) *Potamogeton* Formation,
(*b*) *Nymphæa* Formation,
(*c*) *Scirpus-Typha* Formation,
(*d*) *Cladium-Calamagrostis* Formation,
(*e*) *Fragaria-Polytrichum* Formation,
(*f*) *Rhus-Alnus* Formation,
(*g*) *Prunus-Acer* Formation.

The above structure of vegetation is not exemplified in totality in any one portion of the area characterized as Lagoon B. This is a semi-marshy lagoon, U-shaped, with several small ponds scattered here and there, and probably mainly inundated in very wet periods. One

of the small ponds has an area of *Nymphæa* with a few *Potamogetons* still remaining; outside of this being a zone consisting of the *Typha latifolia* consocies of the *Typha-Scirpus* formation.

Surrounding the zone of *Typha* is the *Cladium-Calamagrostis* formation, which in several places is a number of rods wide, and in fact occupies a large part of the lagoon. There is a very marked segregation of this formation into zones; an inner one consisting of the *Cladium mariscoides* consocies, and an outer one consisting of the *Calamagrostis canadensis* consocies. The latter presents a very beautiful *Aster ericoides* aspect during late September.

The *Fragaria-Polytrichum* Formation.

At the outer border of the *Cladium-Calamagrostis* meadow appears a rather broken zone, characterized by *Polytrichum* and *Fragaria*. This formation appears to be a sort of "filler" between the meadow and the succeeding shrub-zone. The old shore of the lagoon is here rather wide and has almost no slope, and the *Fragaria-Polytrichum* formation appears only where there seems to be a space, which cannot be occupied by the shrub-zone by the time that the conditions have become more or less unsuitable for the *Calamagrostis canadensis* consocies.

The typical composition of the formation is:

Facies. —
Fragaria virginiana, *Polytrichum* sp.
Secondary Species. —
Sphagnum sp., *Aster ericoides*,
Rhus typhina, *Alnus incana*,
Salix cordata.

This formation is probably a further development, in conditions of a soil with more humus, of what was termed in the *Cladium-Calamagrostis* formation of Stage F, the *Fragaria* society. A further development of probably the same structure is the *Aronia-Polytrichum* formation skirting the *Sphagnum-Oxycoccus* formation of Cranberry Pond and of which more will be said later. It appears probable that the *Fragaria-Polytrichum* formation is not necessarily a member of the lagoon-marsh-thicket-forest succession, but that it represents, either in whole or in part, a formation belonging essentially to some other succession, having found between the meadow and the shrub-zones certain conditions suitable for its successful intercalation. More will

be said along this line in the discussion of the phyto-geographical relations of the flora of Presque Isle.

Outside of the *Fragaria-Polytrichum* formation, and advancing gradually into that zone, is the *Rhus-Alnus* formation, which is quite well developed, and around the outer border is even passing into a forest-formation, as indicated by the invading *Prunus serotina* and *Acer saccharinum*.

Stage H. — Cranberry Pond.

In the various lagoons or ponds to the south and west of Long Ridge there can be more or less clearly traced a gradual development into ecological conditions and vegetational formations quite dissimilar to those described for the lagoons to the north and west of the ridge.

The habitat most typical of what perhaps can be most definitely designated as the next clearly distinct stage after Stage G, is Cranberry Pond, a long narrow lagoon closely similar to Ridge Pond and comparatively but little older. The lagoon has practically the same water-level as Lake Erie, there being, however, no drainage outlet excepting through seepage, a character common to most of the lagoons of the peninsula. Currents are thus reduced to a minimum, there being no drainage currents, and the action of the wind upon the surface of the lagoon is also very small, owing to the narrowness of the basin and the protection afforded by the tall forest closely surrounding it.

The vegetational formations, proceeding from the middle of the pond to the shore, are as follows:

(*a*) *Potamogeton* Formation,
(*b*) *Castalia-Nymphæa* Formation,
(*c*) *Cephalanthus-Cornus* Formation,
(*d*) *Sphagnum-Oxycoccus* Formation,
(*e*) *Aronia-Polytrichum* Formation,
(*f*) *Rhus-Alnus* Formation,
(*g*) *Prunus-Acer* Formation.

The *Potamogeton* Formation.

With the limited means at hand the writer was unable to make more than a very superficial survey of the deeper waters of the pond, but enough was learned to make it certain that there is more or less *Chara* and *Naias* in the central portion of the pond, and it is quite likely that a more complete examination would reveal the presence of a *Chara* formation in the deepest water and more or less mixed with the *Potamogetons*.

In Lake St. Clair Pieters[75] found that wherever the bottom was of clay or of alluvial origin, the "*Characetum*" covered the bottom from the line of the zone of rushes (*Scirpus*) to a depth of two to seven meters. Where the bottom was sandy the *Charas* were scarce or entirely absent. Although there is every reason to believe that the bottom of Cranberry Pond is sandy, it is probably covered with a considerable deposit of humus, and it is certain that at least some *Chara* grows there; where hunters had poled a small boat back and forth from the shore a number of good sized fragments of *Chara* were obtained.

The *Castalia-Nymphæa* Formation.

This formation in places has become a closely packed zone of *Nymphæa advena*, often twenty-five to thirty feet wide, but more often it consists of a rather weak zone of rather scattering individuals, containing also a few species from the *Potamogeton* formation, *Myriophyllum spicatum*, *Potamogeton natans*, and *Potamogeton pectinatus*. In the deeper parts of the zone are a few plants of *Castalia tuberosa*.

The *Cephalanthus-Cornus* Formation.

One of the most striking features of distinction between the vegetation of Cranberry Pond and the lagoons to the north and east of Long Ridge is the complete supplanting of the *Scirpus-Typha* formation by a zone composed almost entirely of shrubs. The structure of this zone is essentially as follows:

Facies. —
Cephalanthus occidentalis, *Cornus stolonifera*,
Rosa carolina.
Principal Species. —
Salix cordata, *Salix lucida*,
Bidens cernua, *Triadenum virginicum*,
Persicaria laurina, *Persicaria incarnata*,
Dryopteris thelypteris.
Secondary Species. —
Salix nigra, *Salix discolor*,
Nymphæa advena, *Dulichium arundinaceum*,

[75] Pieters, A. J. "The Plants of Lake St. Clair." Michigan Fish Commission, Bull. 2: 6, 9, 1894.

Eleocharis quadrangulata, *Eleocharis obtusa*,
Proserpinaca palustris, *Calamagrostis canadensis*,
Naumbergia thyrsiflora, *Asclepias incarnata*.

The formation as a whole presents very little zonation or alternation within itself. *Cephalanthus* is the only one of the facies that can ever be said to constitute a distinct consocies, it usually being indiscriminately mixed with the other facies. *Rosa carolina* seems sometimes to prefer the outer border of the formation, thus indicating a *Rosa carolina* consocies, but in the present stage such association is not prominent.

The formation constitutes a zone of varying width, in a few places even being absent altogether, but towards the west end of the pond it sometimes reaches a width of about forty feet. The soil is always a saturated muck several inches deep, the pondward side of the zone being usually three to four inches under water and the landward side just above its surface.

The ecological conditions of this habitat are approximately those of the "undrained swamp" as described by Cowles and others.[76] *Cephalanthus* is almost invariably one of the most characteristic facies in the shrub-zone around undrained swamps and ponds, where there has been an accumulation of vegetable matter resulting finally in a saturated muck-soil. Towards the southern part of the glaciated area of the northern states the shrub-formation of the morainal ponds and open swamps consists almost always, in large part, of *Cephalanthus*.[77] Northwards this species gives way to other plants, such as *Cassandra*, willows, etc.

At the west end of Cranberry Pond there is an area of about an acre which is now above water most of the year and which might best be described as a mud-flat. The soil is a black muck and it is now sparsely occupied by young *Cephalanthus* bushes, the open spaces between being partially taken up by *Nymphæa advena*, small and unhealthy, *Hypericum canadense*, *Dulichium arundinaceum*, and *Eleocharis quadrangulata*. This area appears to have only comparatively recently been filled to such an extent that the *Nymphæa* has had to succumb and

[76] Cowles, H. C. "Physiographic Ecology of Chicago and Vicinity," *l. c.*, pp. 147–155, *and* Coulter, S. M. "An Ecological Comparison of Some Typical Swamp Areas." Ann. Rept. Mo. Bot. Gard., 15: 56, March, 1904.

[77] Schaffner, J. H., Jennings, O. E., and Tyler, F. J. "An Ecological Study o Brush Lake." *Proceed. Ohio Acad. Science*, 4: 159–160, 1904.

give place to the *Cephalanthus*. In a few years this area will probably support one of the best examples of the *Cephalanthus-Cornus* formation to be found anywhere on the peninsula.

Ridge Pond, as might be expected, being somewhat younger than Cranberry Pond, has the *Cephalanthus-Cornus* formation less well developed than the latter. In fact most of the vegetation in Ridge Pond corresponding to this formation has a transitional appearance. On the south side of the pond *Scirpus* and *Typha* still remain in considerable quantities, but *Cephalanthus*, *Iris*, *Rosa carolina*, *Proserpinaca*, etc., are invading the habitat quite abundantly. The *Rosa carolina* clings quite closely to the border of the shrub-zone surrounding this habitat, characterized by *Alnus incana* and *Cornus amomum*. The corresponding zone on the north side of the pond is fairly typical of the *Scirpus-Typha* formation, *Cephalanthus* and *Rosa* having merely just begun to invade the habitat.

The *Sphagnum-Oxycoccus* Formation.

The successor to the *Cladium-Calamagrostis* formation under certain conditions is a cranberry bog (*Sphagnum-Oxycoccus* formation). Just what the conditions are, which determine whether the wet meadow shall pass into a cranberry bog, or into a *Rhus-Alnus* thicket, are not known to the writer. Where the shores are wide and low, the accumulation of humus in the saturated, undrained *Calamagrostis* marsh or wet meadow, may finally bring about edaphic conditions too cold and too acid for the ready ecesis of the shrubs, thus permitting the entrance of the *Sphagnum-Oxycoccus* formation. Whether this may be the true explanation or not, the formation appears not to be a regular stage of the succession, but is rather to be regarded as a formation belonging to a more northern succession, and, like the *Fragaria-Polytrichum* formation, to which it may be a succeeding stage, it is to be here regarded as an intercalation.

The structure of this formation, as exemplified at the eastern end of Cranberry Pond, is as follows:

Facies. —
Oxycoccus macrocarpus, *Sphagnum* sp.
Secondary Species. —
Iris versicolor, *Pinus strobus*,
Acer rubrum, *Acer saccharinum*
Alnus incana, *Spiræa latifolia*,

Eleocharis quadrangulata, *Eleocharis obtusa*,
Proserpinaca palustris, *Calamagrostis canadensis*,
Naumbergia thyrsiflora, *Asclepias incarnata*.

The formation as a whole presents very little zonation or alternation within itself. *Cephalanthus* is the only one of the facies that can ever be said to constitute a distinct consocies, it usually being indiscriminately mixed with the other facies. *Rosa carolina* seems sometimes to prefer the outer border of the formation, thus indicating a *Rosa carolina* consocies, but in the present stage such association is not prominent.

The formation constitutes a zone of varying width, in a few places even being absent altogether, but towards the west end of the pond it sometimes reaches a width of about forty feet. The soil is always a saturated muck several inches deep, the pondward side of the zone being usually three to four inches under water and the landward side just above its surface.

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The structure of this formation, as exemplified at the eastern end of Cranberry Pond, is as follows:

Facies. —
Oxycoccus macrocarpus, *Sphagnum* sp.
Secondary Species. —
Iris versicolor, *Pinus strobus*,
Acer rubrum, *Acer saccharinum*
Alnus incana, *Spiræa latifolia*,

Aronia melanocarpa, *Rubus hispidus*,
Eriophorum gracile.

From certain historical data it appears that half a century ago cranberries were abundant on Presque Isle. For the particular benefit of the people of Erie, laws were passed by the State in 1841, imposing a fine of $10 to $25 for picking cranberries before October 1, "Cranberry Day." Probably the *Sphagnum-Oxycoccus* formation of Cranberry Pond was formerly quite extensive. Around most of the pond the shores have a gentle slope, and each formation is thus given the opportunity to occupy a wide zone of fairly uniform ecological conditions. At the present time the total area of the *Sphagnum-Oxycoccus* formation on Presque Isle probably does not exceed one-half acre. Big Chimney Pond formerly contained considerable *Oxycoccus*, but with the laying of the intake pipe for the Erie waterworks this pond was dredged and later largely filled in with sand, so that very little of the formation is left.

The fate of the *Sphagnum-Oxycoccus* formation around Cranberry Pond is easily to be recognized. There are many seedlings of *Pinus strobus*, *Acer rubrum*, *Acer saccharinum*, together with *Spiræa* and *Aronia*, so that eventually the zone will be supplanted by a forest.

The *Aronia-Polytrichum* Formation.

Skirting the outer and higher side of the *Sphagnum-Oxycoccus* formation around Cranberry Pond there is a zone consisting almost exclusively of two species, the structure of the formation being as follows:

Facies. —
Polytrichum sp., *Aronia nigra*.
Secondary Species. —
Vaccinium corymbosum, *Populus tremuloides*,
Rubus hispidus, *Prunus serotina*,
Prunus virginiana.

There is but a limited area of this zone, about one hundred feet long by fifteen to eighteen feet wide, but the structure of the formation is very distinct and the plants occupy the habitat very completely. The *Aronia* occurs in dense clumps (families and communities) between which the *Polytrichum* forms a matted heath. Of the secondary species there are a very few individuals present, these being mostly seedlings and confined to the borders of the formation.

The *Rhus-Alnus* Formation.

The *Rhus-Alnus* formation is not prominent about Cranberry Pond although around Ridge Pond it is still a strong zone. Around Cranberry Pond the formation consists almost entirely of the *Alnus incana* consocies, but where the *Aronia-Polytrichum* zone is present, the former is absent altogether. In fact, the two formations are apparently coördinate, the *Aronia-Polytrichum* formation occupying the wider zone of a gently sloping shore, while the *Alnus incana* consocies occupies the narrower zone of the steeper shores towards the middle and west end of the pond, where the water comes closer to the forest and the zone is more deeply shaded.

Where the *Alnus incana* consocies is present, there is no undergrowth, except that seedlings and young trees of *Acer saccharinum* are more or less numerous.

The *Prunus-Acer* Formation.

Back of the *Rhus-Alnus* formation and extending to the top of the bank in the habitat of the former *Populus-Salix* formation, following closely behind the *Alnus* thicket, is a narrow zone with the following structure:

Facies. —
Acer saccharinum, *Prunus serotina*.
Secondary Species. —
Quercus velutina, *Quercus palustris*,
Quercus borealis, *Acer rubrum*,
Smilax herbacea, *Aralia racemosa*,
Phryma leptostachya, *Galium aparine*,
Galium circæzans, *Osmorhiza claytoni*,
Dryopteris spinulosa.

This formation derives many of its species from the adjoining *Quercus velutina* forest of the Beach-Sand-Plain-Heath-Forest succession but, as the encircling zones advance with the filling up of the lagoon, the habitat comes more and more to occupy a habitat with a black, undrained, more or less acid soil, and such species as are peculiar to this environment more and more predominate in this formation. With the advent of more shady conditions the *Prunus* disappears, leaving the zone more typically an *Acer saccharinum* consocies, but nowhere on the peninsula does this consocies assume any considerable importance. It is usually crowded out by the *Quercus velutina* formation

from above and the hydrophytic forest, which later develops on the muck-soil below. In the pure tamarack forest at the "first Sister Lake," in the Huron River Valley of Michigan, Weld finds coming in a formation composed of almost exactly the same species here included in the *Prunus-Acer* formation.

Stage I. — Ponds R, S, U, V, north end of P.

The climax formations of the Lagoon-Marsh-Thicket-Forest Succession, for Presque Isle at least, are to be seen in the Chimney Ponds (R, S, U, and V). The arrangement of the formations at this stage being typically as follows:

(*a*) *Potamogeton* Formation,
(*b*) *Castalia-Nymphæa* Formation,
(*c*) *Decodon-Persicaria* Formation,
(*d*) *Cephalanthus-Cornus* Formation,
(*e*) *Rhus-Alnus* Formation,
(*f*) *Quercus-Acer* Formation.

The ecological conditions obtaining in the Chimney Ponds are evidently very closely similar to those obtaining in undisturbed glacial ponds in the northern states. The Chimney Ponds are quite old and are considerably protected from the winds of the lake by the surrounding forest. The accumulation of vegetable matter has been sufficient to cause the basins to be fringed and lined with a layer of humus, which by humification has been reduced mainly to the form of a black, semi-liquid muck. The drainage is merely that due to seepage through the porous sand of the peninsula, ordinarily very little water passing either into or out of the ponds, excepting such as is necessary to maintain the water-level against fluctuations due to precipitation, evaporation, or fluctuations in the level of the lake. Even then the seepage is not rapid, and the ponds have on the whole a very uniform water-level. Such exchanges of water must to some extent at least prevent the accumulation of acids in the pond water, and thus at the same time permit the conversion by humification of the vegetable débris into black muck.

Within recent years several ecological studies have been made of glacial ponds and small lakes throughout the region bordering the Great Lakes. In undisturbed conditions throughout this region the ponds and lakes have practically the same formations, arranged in essentially the same order as has been described for the Chimney

Ponds. The species are not always the same in the corresponding formations, but they are usually closely similar in ecological structure, and are quite often nearly related systematically.

The *Chara* Formation.

In basins with a clay or alluvial bottom, the deeper portions are generally occupied in the Great Lakes region by a *Chara* formation, which with certain of the Cyanophyceæ may eventually result in the deposition of more or less marl.[78] As was stated in the discussion of the *Potamogeton* formation of Cranberry Pond, *Chara* has been found to prefer clayey or alluvial pond-bottoms to sandy ones, but, as the plant was collected in Pond U together with *Myriophyllum* and *Naias*, it can be assumed to be present in the other Chimney Ponds also.

The *Potamogeton* Formation.

The *Potamogeton* formation is well developed in all of the Chimney Ponds and, as represented there, the vegetational structure is typically as follows:

Facies. —

Potamogeton pectinatus, *Potamogeton lonchitis*,
Potamogeton heterophyllus.

Secondary Species. —

Potamogeton lucens, *Potamogeton natans*,
Vallisneria spiralis, *Philotria canadensis*,
Naias flexilis, *Myriophyllum spicatum*,
Lemna minor.

This formation, as listed, may be taken as representative of the mature *Potamogeton* zone whether at Presque Isle; Brush Lake, Ohio, where *Potamogeton zosteræfolius*, *Potamogeton lucens*, *Ceratophyllum demersum*, *Myriophyllum*, and *Chara*, are listed as typical species;[79] or in the Three Sister Lakes, Michigan (near Ann Arbor), where *Potamogeton lucens* and *Potamogeton zosteræfolius* are facies.[80]

[78] Davis, C. A. "Contribution to the Natural History of Marl." *Journ. Geology*, 8: 485, 1900, and "A Second Contribution to the Natural History of Marl." *Journ. Geology*, 9: 491, 1901.

[79] Schaffner, J. H., Jennings, O. E., and Tyler, F. J. *l. c.*, pp. 153–154.

[80] Weld, L. H. "Botanical Survey of the Huron River Valley, II. A Peat Bog and Morainal Lake." *Bot. Gaz.*, 37: 39–40. January, 1904.
Reed, H. S. "Botanical Survey of the Huron River Valley, I. The Ecology of a Glacial Lake." *Bot. Gaz.*, 34: 129. 1902.

The *Castalia-Nymphæa* Formation.

The water lily zone (*Castalia-Nymphæa* formation) is almost as regularly present in the small ponds and lakes of the glaciated region of the northern states as is the *Potamogeton* formation. It occupies water, usually between the depths of one and one-half and six feet, where the bottom is covered to a depth of often several inches with a black mud composed very largely of humus. In the Chimney Ponds the formation consists of the following species:

Facies. —
Castalia tuberosa, *Nymphæa advena.*
Principal Species. —
Pontederia cordata.
Secondary Species. —
Sagittaria latifolia, *Potamogeton natans*,
Naias flexilis, *Myriophyllum spicatum*,
Lemna minor, *Utricularia vulgaris*,
Philotria canadensis.

There is a strong tendency towards zonation in this structure. Wherever *Castalia* appears it prefers the deeper part of the habitat, thus forming the *Castalia* consocies, with which are usually associated some of the *Potamogetons* — notably *P. natans*, and often *Naias* and *Myriophyllum.*

The outer (shoreward) part of the formation is characterized by *Nymphæa advena*, forming thus the *Nymphæa advena* consocies, with which is associated *Pontederia cordata*, which during early and middle summer becomes prominent in beautiful clumps (families and communities), characterizing thus the *Pontederia cordata* aspect. Other species in this consocies are *Sagittaria latifolia*, *Lemna minor*, *Utricularia vulgaris*, and scattering individuals of the other secondary species of the consocies.

The *Castalia-Nymphæa* formation probably builds up the soil more rapidly than does any other formation in the pond. The rhizomes of the characteristic plants are for the most part quite large, and both when alive and when decayed contribute quite considerably to the increase of the soil substratum. Furthermore the tangle of fine-leaved submerged vegetation together with the long petioles and broad leaves of the water-lilies brings about a freedom from water-currents, and makes more certain the deposition within the limits of the zone of its abundant annual accumulation of vegetable débris.

Eventually with the continued addition of humus to the soil of this zone, there will be built up a belt of deep, semi-liquid muck just inside of the *Cephalanthus-Cornus* shrub-zone, and, when this has come to within a few inches of the surface of the water, the *Castalia-Nymphæa* formation will find the conditions unsuitable to such an extent that it will be supplanted by an association of plants constituting a new formation.

The *Decodon-Persicaria* Formation.

The *Decodon-Persicaria* formation occupies a very distinct zone in some of the Chimney Ponds, in water of a depth from four to twelve inches, but with the older clumps forming mounds above the surface of the water. The soil is always made up of a semi-liquid muck of considerable depth, and represents the abandoned habitat of the *Castalia-Nymphæa* formation. Pond U has much of this formation, constituting a distinct zone, while Pond V is now almost filled with *Decodon* families and communities, the middle of the pond being in the last stages of the *Castalia-Nymphæa* formation. The new formation is present sparingly in Ponds T, S, and R, conspicuously so in Z, and forms several strong communities in the west end of Long Pond.

The typical structure of the formation is as follows:

Facies. —
Decodon verticillatus, *Persicaria fluitans.*
Principal Species. —
Solanum dulcamara.
Secondary Species. —
Naumbergia thyrsiflora, *Cephalanthus occidentalis*,
Bidens cernua, *Scutellaria lateriflora*,
Cicuta bulbifera, *Scirpus cyperinus*,
Alisma plantago-aquatica, *Sagittaria latifolia.*

There is a tendency in this formation towards the segregation of two consocies: the *Decodon verticillatus* consocies in the shallower water, and the *Persicaria* consocies in the deeper water. Of the two, however, the former is here much more vigorous, and, where it is best developed, occupies the whole habitat to the exclusion of the latter consocies.

In other localities these consocies have been regarded as different formations but at Presque Isle their relation is best described as zonation within the same formation.

Around R, before the vegetation was destroyed by the laying of the waterworks intake-pipe, there appeared some intensely interesting examples of alternation between different formations. There may have been disturbances within recent years due to the washing in of water from the bay or the lake, either of which is but a few feet distant from the pond. At any rate there are three formations represented in the zone between the *Castalia-Nymphæa* formation and the *Cephalanthus-Cornus* formation: viz., the *Decodon-Persicaria* formation, the *Sphagnum-Oxycoccus* formation, and the *Scirpus-Typha* formation. The relative positions of the *Sphagnum-Oxycoccus* and *Cephalanthus-Cornus* formations are here just the reverse of what they are around Cranberry Pond, although they must be regarded as occupying more typical positions around Cranberry Pond. Of the three alternating formations mentioned above the *Decodon-Persicaria* formation must be regarded as the normal formation. The *Sphagnum-Oxycoccus* formation is an intercalated formation, representing normally a stage in another succession, while the *Scirpus-Typha* formation normally represents an early stage in the succession under consideration, its presence here being probably due to the inwashing of fresh sand.

The *Cephalanthus-Cornus* Formation.

The perennial tangle of vegetation in the *Decodon-Persicaria* zone is well adapted to catch and hold any vegetable débris blowing in from the surrounding forest or floating on the surface of the pond. This, together with the accumulation of vegetable matter derived directly from the plants of the formation itself, gradually builds up the soil to such a level that conditions become suitable for the ecesis of the shrubs of the *Cephalanthus-Cornus* formation.

The structure of the formation here is essentially the same as that described for the formation under Stage H, excepting that the *Cephalanthus-occidentalis* consocies is more prominent, and the number of secondary species is reduced by the disappearance of some of the more hydrophytic species — as *Proserpinaca palustris* and *Nymphæa advena*.

The *Rosa carolina* consocies is also more clearly defined and can be seen to show a decided preference for the shoreward zone of the habitat. A little pond at the west end of Long Pond has been entirely filled in, and the only trace of the *Cephalanthus-Cornus* formation to be seen is a *Rosa carolina* consocies, which is being killed out

The *Rhus-Alnus* Formation.

Outside of the *Cephalanthus-Cornus* formation there is present in most of the Chimney Ponds more or less of a zone of the *Rhus-Alnus* formation. Most of the ponds are surrounded by forest-trees and, in the more or less shaded conditions, the *Rhus* has given place to the pure *Alnus incana* consocies. In the more open places, however, certain other species become more or less prominent and the formation there exhibits the following structure:

Facies. —
Rhus typhina, *Alnus incana*.
Principal Species. —
Sambucus canadensis.
Secondary Species. —
Acer rubrum, *Acer saccharinum*,
Sassafras sassafras, *Salix nigra*,
Cornus stolonifera, *Cornus amomum*,
Cephalanthus occidentalis, *Vaccinium corymbosum*,
Dryopteris thelypteris.

The *Ulmus-Acer* Formation.

With the advance of the shrub-formations towards the center of the pond, there appears at the rear of the *Rhus-Alnus* formation, or, more generally the *Alnus incana* consocies, a semi-hydrophytic forest-formation which includes also most of the area occupied in the earlier stage by the *Acer saccharinum* consocies of the *Prunus-Acer* formation. The habitat of this formation consists, of course, of a black muck soil, but little above water-level and imperfectly drained. There is protection from strong air-currents by the surrounding forest and, below the forest-cover afforded by the *Alnus*, there is deep shade, with freedom from abrupt extremes of heat and cold.

The ecological conditions are apparently those required by a semi-hydrophytic forest, and, as thus far developed on Presque Isle, the structure of the formation is typically as follows:

Facies. —
Acer rubrum, *Ulmus americana*.
Secondary Species. —
Fraxinus americana, *Liriodendron tulipifera*,
Fraxinus nigra, *Nyssa sylvatica*,

Quercus palustris,	*Quercus rubra,*
Acer saccharinum,	*Salix nigra,*
Toxicodendron pubescens,	*Viburnum opulus,*
Psedera quinquefolia,	*Galium circæzans,*
Galium triflorum,	*Unifolium canadense,*
Phryma leptostachya,	*Impatiens biflora,*
Ilex verticillata,	*Bæhmeria cylindrica,*
Smilax herbacea,	*Salomonia biflora,*
Onoclea sensibilis,	*Osmunda claytoniana,*
Osmunda spectabilis,	*Osmorhiza claytoni,*

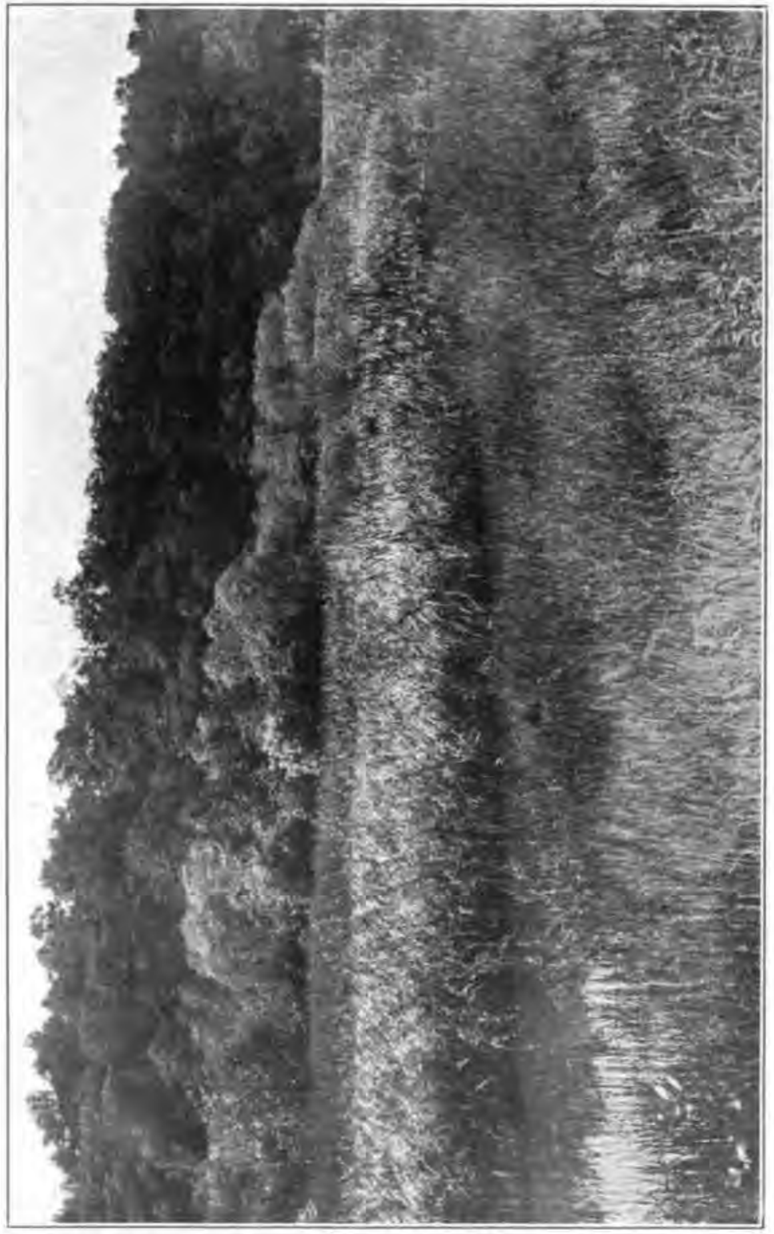
Trillium erectum.

Vegetation other than trees is not a prominent feature of this forest. Many of the herbaceous and shrubby species enumerated above occur only sparingly and are really constituents of another formation.

The total area covered by the formation is not large. In the vicinity of the Chimney Ponds it is confined to irregular zones around the borders of the basins. There is, however, marking the position of extinct ponds, a circular area of this formation about 30 rods in diameter south of the west end of Long Pond and another smaller one to the northeast of Big Chimney Pond, R, near the bay.

The ecological conditions obtaining in the habitat of the *Ulmus-Acer* formation at Presque Isle are closely similar in most respects to those obtaining about numerous filled-in basins throughout the southern part of the glaciated area of the northern states. There is always the black muck-soil, imperfectly drained, more or less acid, and with a high water content, the position being more or less sheltered by neighboring banks. At a higher elevation, or farther north, the normal formation in such a habitat is the Tamarack forest, or, later, the Arbor Vitæ forest.[81] It is not probable that the *Ulmus-Acer* formation represents the climax forest for these pond basins, but that, with the annual accumulation of considerable quantities of forest litter, much of which at Presque Isle blows into it during the fall and winter from the more open and exposed *Quercus velutina* formation, the soil will finally become higher and more xerophytic to such an extent that the *Quercus velutina* formation will be able to invade and eventually occupy the habitat. Even under present conditions there

[81] Whitford, H. N. "The Genetic Development of the Forests of Northern Michigan." *Bot. Gaz.*, 31 : 312–316, May, 1901.



Outlet of pond at Head, looking across towards the mainland escarpment. Beginning in the immediate foreground the following zoned formations are shown: *Alnus-Salix*, *Carex-Phragmites*, *Typha-Scirpus*, then shrubs at the base of escarpment. Photographed June 10, 1906.

is an occasional black oak in the habitat and, although they are as yet merely saplings, they appear healthy and vigorous.

At the "Head" there is a pond Z (see Plate LI) which constitutes an ecological habitat considerably different from the ponds and lagoons described above. This pond is fed by springs issuing from the lake bluff and it also receives a considerable run-off from the land above —a couple of small streams debouching at this point. As a consequence, there is a considerable outward current flowing through the outlet into Presque Isle Bay, and the water in the pond was found on several visits to be several degrees colder than in the ponds out on the peninsula.

The banks and bottom of this pond are not entirely composed of the clean white sand, which constitutes the basins of the ponds and lagoons on the peninsula, but have a considerable mixture, especially on the landward side, of fluvial material; around most of the basin there is enough silt and clay mixed with the sand to form a quite compact and firm soil. Formerly, the stream now emptying into the lake west of the head of the peninsula, emptied into the bay just inside of the neck of the peninsula, and doubtless much of the soil now composing the more landward parts of the head was deposited as a sort of alluvial fan inside of the peninsula.

The vegetation of the basin of the pond is in many respects quite dissimilar to the vegetation of the ponds and lagoons of the peninsula proper. The sequence of formations on the lakeward side of this pond is as follows:

(*a*) *Chara* Formation,
(*b*) *Potamogeton* Formation,
(*c*) *Castalia-Nymphæa* Formation,
(*d*) *Decodon-Persicaria* Formation,
(*e*) *Typha-Scirpus* Formation,
(*f*) *Carex-Phragmites* Formation,
(*g*) *Alnus-Salix* Formation.

The *Chara* Formation.

As may be seen from the Waldameer Park bridge, which crosses the pond at about its middle, the *Chara* formation occupies a considerable portion of the deeper part of the pond. The growth is quite dense and quite completely covers the bottom of the pond.

The *Potamogeton* Formation.

The *Potamogeton* formation has here almost precisely the same structure as described for the climax stages in the ponds of the peninsula proper, for instance in the Chimney Ponds.

The *Castalia-Nymphæa* Formation.

This formation is comparatively a strong one in the pond. Its structure is typically as follows:

Facies. —
Nymphæa advena, *Castalia tuberosa.*
Principal Species. —
Pontederia cordata.
Secondary Species.—
Brasenia schreberi, *Potamogeton natans*,
Naias flexilis, *Myriophyllum spicatum*,
Utricularia vulgaris, *Philotria canadensis*,
Vallisneria spiralis.

There is a tendency here as elsewhere to the segregation by zonation of an inner *Castalia* consocies, including some of the *Potamogetons*, and an outer *Nymphæa* consocies, including the *Pontederia cordata* society.

The *Decodon-Persicaria* Formation.

The *Decodon-Persicaria* formation is very closely similar in ecological structure to the corresponding formation in Stage I described above, excepting that the *Decodon-verticillatus* consocies is but weakly developed. In Stage I the formation contains a number of secondary species, which probably more properly belong to the *Scirpus-Typha* formation, but which have been crowded forward by the shrub-zones. On the lakeward side of the pond there has been no crowding forward in this manner, and there is a clearly defined zone similar to the *Typha-Scirpus* formation of the earlier stages of the succession, although somewhat more complex in composition.

The *Typha-Scirpus* Formation.

The structure of this formation around Pond Z is typically as follows:

Facies.—
Scirpus americanus, *Scirpus validus*,
Typha latifolia.
Principal Species.—
Bidens cernua.
Secondary Species.—
Cicuta bulbifera, *Iris versicolor*,
Sagittaria latifolia, *Sparganium eurycarpum*,
Rumex altissimus, *Lemna minor*,
Nostoc sp.

The *Bidens cernua* society determines during late summer the only conspicuous aspect of the formation. *Cicuta bulbifera* in places attains to considerable importance, but is never very conspicuous. In the *Typha latifolia* consocies the *Sparganium* shows a strong tendency towards the segregation of a secondary zone on the shoreward side of the formation in water even shallower than that occupied by the *Typha*.

The *Carex-Phragmites* Formation.

The outer bank of the pond Z has just outside of the *Typha-Scirpus* formation a zone occupied by grasses and sedges and extending from the wet bank of humus just above the water's edge into the pond to a depth of three to four inches. There is, however, considerable fluctuation in the water-level of the pond, and during periods of heavy rainfall the whole habitat is often inundated.

The structure of the formation is as follows:

Facies.—
Carex stricta angustata, *Phragmites phragmites.*
Principal Species. —
Aster novæ-angliæ, *Zizania aquatica.*
Secondary Species. —
Scirpus americanus, *Scirpus fluviatilis*,
Dryopteris thelypteris, *Calamagrostis canadensis*,
Panicularia nervata, *Dulichium arundinaceum*,
Carex hystricina, *Carex lanuginosa*,
Carex aquatilis, *Carex prasina*,
Carex muhlenbergii, *Naumbergia thyrsiflora*,
Galium aparine, *Scutellaria lateriflora*,
Scutellaria galericulata.

This formation is somewhat intermediate in structure between the corresponding formations of the ponds and lagoons of the peninsula proper and the open marshes along the bay-side of the peninsula. The pond originally must have been part of the bay, which with the formation of a bar across the narrow channel was cut off from the main body of the bay, and was then filled in to a considerable extent by vegetable remains and alluvial material from the mainland.

Before the segregation of the pond from the bay it probably supported a littoral marsh, such as is now to be found along the shore to the east, and the *Carex-Phragmites* formation is in part derived from this former structure.

The *Salix-Alnus* Formation.

The *Carex-Phragmites* formation is closely followed by a shrub-formation, characterized by *Salix* and *Alnus*, as follows:

Facies. —

Salix nigra, *Alnus incana*.

Secondary Species. —

Equisetum hyemale,	*Cardamine pennsylvanica*,
Mentha canadensis,	*Panicularia nervata*,
Galium aparine,	*Impatiens biflora*,
Cornus stolonifera,	*Lycopus americanus*,
Sambucus canadensis,	*Lobelia syphilitica*.

This formation is but sparingly developed along the lakeward bank of the pond, but it forms a considerable thicket at the lower end of the pond around the outlet. The soil here is a black muck containing more or less sand, the edaphic conditions of the habitat being quite similar to those found along the average alluvial flood-plain in the northern states.

The Bay-Marsh-Thicket-Forest Succession.

Along the bay shores of the peninsula there is a rather complex series of formations, constituting what may be termed the Bay-Marsh-Thicket-Forest Succession. The irregular contour of the peninsula on the bay-side results in quite widely differing conditions at different points due to the action of the surf and water-currents and the accumulation of drift. The different environments thus brought about are each characterized by correspondingly different vegetational structures, which may be roughly classified as follows, upon the basis of habitat:

A. — *The Marsh.* — This habitat comprises those shores exposed to the waves, but having usually shallow water and a gently sloping sandy or gravelly bottom.

B. — *The Cove.* — The cove habitat comprises the indentations of the shore line — coves, bays, etc. — which are generally well protected from wave action and have deeper water than the marsh.

C. — *The Driftwood Habitat.* — This habitat comprises those shores, which are so situated with respect to wind and current as to be subjected to the accumulation of driftwood.

The Marsh Habitat.

This habitat is represented along a large part of the shore of the bay. The vegetational structures along the narrow neck of the peninsula near the Head, enumerated from the water to the shore, are as follows:

(*a*) *Scirpus* Formation,
(*b*) *Salix discolor-lucida* Formation,
(*c*) *Solidago-Meibomia* Formation.

The *Scirpus* Formation.

The *Scirpus* formation consists of the two facies, *Scirpus validus* and *Scirpus americanus*. The former species constitutes the advance guard and frequently occurs far out in the bay, where the water is six feet or more in depth. The *Scirpus americanus* consocies, however, occurs nearer the shore, and, as in the recently formed lagoons at the eastern end of the peninsula, it may occur even on the beach several inches above the ordinary water-line.

This formation is evidently of considerable importance in determining what the contour of the shore shall be, both from the protection it affords the shore, and from the part it plays in the actual outbuilding of the shore. The plants have strong rapidly-growing root-stocks, and, once having accomplished ecesis, families and communities are soon formed. The slender wiry stems and leaves bend with the wind and wave and are rarely broken, even in the most severe storms. With the formation of ecological families and communities the rushes, growing thickly together, act as an impediment to drifting sand and the bottom is thus sometimes built up quite rapidly where otherwise the sand would not have come to a permanent rest. The bottom is thus built up not only in the area actually occupied by the

plants themselves but also in the area intervening between them and the shore.

The *Salix discolor-lucida* Formation.

Facies. —

Salix discolor, *Salix lucida*.

Secondary Species. —

Salix sericea, *Salix nigra*,
Salix cordata, *Melilotus officinalis*,
Persicaria laurina, *Cardamine pennsylvanica*,
Bidens connata, *Argentina anserina*,
Sambucus canadensis, *Hibiscus moscheutos*.

With the development of the outlying *Scirpus* formation there is usually an accumulation of debris on the low beach. This débris consists mainly of dead *Scirpus* leaves and stems, washed up during the winter and spring. It becomes matted together and packed down with sand, so that the shore usually grows outward in little ridges of a foot or fifteen inches in width and three or four inches high. Behind these little ridges miniature lagoons are sometimes formed. In this habitat the *Salix discolor-lucida* formation is at its best, reaching on the outside to the water's edge and meeting there the *Scirpus* formation. Occasionally there is a weak intervening development of the *Cakile-Xanthium* formation, but, as far as found, this formation was here represented only by the *Xanthium commune* consocies.

The *Salix discolor-lucida* formation is particularly well developed along the narrow neck of the peninsula east of the Head. There are also several smaller stations east of the region of the Chimney Ponds. Where by alternation *Salix discolor* and *Salix lucida* are absent, the secondary species occupy the habitat. The *Salix lucida* consocies is comparatively much less important in this habitat, but in the Drift-wood Habitat it is more important than is the *Salix discolor* consocies.

The *Solidago-Meibomia* Formation.

Between the *Salix cordata* thicket and the xerophytic sand-plain to the rear there is usually a zone characterized by various Leguminosæ and Compositæ. The usual path of hunters is just back of the fringing zone of willows and the sand there has been enriched by the vegetable débris trodden into it, so that in places there has been formed a rather firm, compact, dark-colored soil, comparatively rich

in humus and constituting altogether a very favorable habitat for certain weeds.

The structure of this formation is typically as follows:

Facies. —

Solidago canadensis, *Meibomia canadensis*.

Principal Species. —

Anemone canadensis.

Secondary Species.

Lactuca canadensis, *Melilotus officinalis*,
Strophostyles helvola, *Trifolium pratense*,
Trifolium repens, *Ranunculus abortivus*,
Poa compressa, *Vitis vulpina*,
Plantago lanceolatus, *Mentha piperita*,
Mentha cardiaca, *Carduus arvensis*,
Erechtites hieracifolia, *Xanthium commune*,
Barbarea barbarea.

In certain respects the formation resembles a roadside formation. In a few spots a thin sod has formed, composed of *Poa compressa*. During early summer, June, there is an aspect characterized by the *Anemone canadensis* society, but the main mass of vegetation develops later in the season, the facies becoming most conspicuous in late summer and early fall.

In X and Y (see map) and along the bay-shore to the Chimney Ponds including T also, the vegetation is in a much more highly developed stage, owing doubtless to the longer period in which it has been allowed to develop undisturbed. The occasional incursions of the lake through the narrow neck of the peninsula to the west since 1861 must have considerably disturbed, if not totally destroyed, the vegetation of the marsh along that shore, and as a consequence the vegetation there represents a younger stage than does the vegetation farther to the west, where the development has been continuous and undisturbed.

The structure of the vegetation in the more highly developed marsh is typically as follows:

(*a*) *Scirpus* Formation,
(*b*) *Phragmites-Typha* Formation,
(*c*) *Cladium-Calamagrostis* Formation,
(*d*) *Rhus-Alnus* Formation,
(*e*) *Ulmus-Acer* Formation.

The *Scirpus* Formation.

The *Scirpus* formation is here much more extensive than in the habitat just referred to. It has a maximum width of perhaps one-third of a mile, and in places forms a quite dense growth, which quite effectually calms the waves of ordinary storms. Zonation within the formation is clearly evident in the deeper zone (consocies), characterized by *Scirpus validus*, and in the shallower zone characterized by *Scirpus americanus*. There are a very few isolated families of *Pontederia cordata* and *Sagittaria rigida* mainly in the *Scirpus validus* consocies.

The *Phragmites-Typha* Marsh Formation.

The shallower part of the habitat, occupied in the earlier stage by *Scirpus americanus*, has now been taken over by a well marked formation with the following structure:

Facies. —
Phragmites phragmites, *Typha latifolia*.
Principal Species. —
Zizania aquatica.
Secondary Species. —
Sagittaria latifolia, *Sparganium eurycarpum*,
Persicaria laurina, *Juncus canadensis*.

This formation, as compared with the *Scirpus-Typha* formation of the ponds and lagoons at the northern end of the peninsula, presents some interesting differences. In the lagoons *Scirpus validus*, although occupying the deeper part of the habitat, never occurs in so deep water as it occupies in the bay, and it usually alternates in the ponds with *Typha latifolia*. With the *Typha*, however, the case is different. It occupies about the same depth of water as in the ponds and lagoons, rarely more than fifteen to eighteen inches deep. This may be due, perhaps, to the inability of the *Typha* to cope with the surf in the bay.

The formation exhibits one marked aspect characterized by *Zizania aquatica*, this society filling in the areas not occupied by the *Phragmites* and *Typha* consocies, and, during the latter half of the season, largely obscuring the associated secondary species.

The *Phragmites-Typha* formation is characterized, in a general way, by the possession of large rootstocks and the production of a rather large amount of aerial and submerged vegetation, which each season adds materially to the humic content of the soil, thus producing in a

comparatively short time a deposit of muck-soil. The protection afforded by the outlying *Scirpus* formation is usually so efficient, that almost no sand is carried into the habitat even in the most violent storm, and as a consequence the upper six or eight inches of the soil, when finally built up to the water level, is usually found to be a pure black or dark brown humus.

The *Cladium-Calamagrostis* Formation.

With the formation of a humic soil, the surface of which is ordinarily during the summer above water-level, there is created a habitat in which the *Phragmites-Typha* formation is forced to give way to the *Cladium-Calamagrostis* formation, thus constituting a wet meadow:

Facies.—
Cladium mariscoides, *Calamagrostis canadensis*.
Principal Species.—
Aster ericoides, *Parnassia caroliniana*,
Gentiana andrewsii.
Secondary Species.—
Fragaria americana, *Rubus hispidus*,
Linum medium, *Solidago canadensis*,
Leptorchis loeselii, *Blephariglottis peramœna*,
Dryopteris thelypteris *Argentina anserina*,
Polytrichum sp.

One of the finest examples of the wet-meadow formation is to be seen at Y. Here the meadow occupies a depression about one-fourth of a mile in length and about twenty rods wide. It is bordered on nearly all sides by shrubs, but at the eastern end has an opening into the bay which is now occupied by the *Phragmites-Typha* formation, while farther out is the *Scirpus* formation.

There is here practically no difference between the *Cladium-Calamagrostis* formation and the same formation around the ponds and lagoons, excepting that the *Cladium mariscoides* consocies plays here a much less important part in the succession, the *Calamagrostis canadensis* consocies almost immediately succeeding the *Phragmites-Typha* formation. This is probably due to the somewhat different edaphic conditions obtaining in the two habitats. The soil around the newly formed ponds and lagoons, when first occupied by the *Cladium*, is largely sand with more or less humus, the *Calamagrostis* coming in with the accumulation of humus. In Y, however, the soil, as accu-

mulated by the *Phragmites-Typha* formation, is almost exclusively humus, and the *Cladium*, although usually in evidence in the earlier part of the formation, is relatively unimportant in it. Along the eastern border of Y there is now some *Cladium* and in the central portion and towards the outlet in the more moist spots there still remain some *Phragmites* and *Typha*.

There is in this formation an early autumn aspect determined by the *Aster ericoides* society, but occupying rather restricted areas. During late summer a quite conspicuous aspect is determined along the northern side of the meadow by the *Parnassia-Gentiana* society, this being the only station for this society on the peninsula.

The *Rhus-Alnus* Formation.

The wet meadow, *Cladium-Calamagrostis* formation, is being everywhere invaded by a shrub-formation similar to that around the ponds and lagoons described as the *Rhus-Alnus* formation, but differing somewhat in composition, owing probably to differences in the environment. The structure of the formation here is typically as follows:

Facies. —
Rhus typhina, *Alnus incana*.
Principal Species. —
Solidago canadensis *Cornus amomum*.
Secondary Species. —
Fragaria virginiana, *Myrica caroliniana*,
Argentina anserina, *Vitis vulpina*,
Salix discolor, *Salix cordata*,
Toxicodendron pubescens, *Rubus* sp.,
Meibomia dillenii.

There is here again the larger percentage of humus in the soil, which may be more or less directly the reason for the difference in the composition of the formation. *Rhus typhina* although present is not abundant, and the thicket is chiefly composed of the *Alnus incana* consocies.

The formation presents some alternation. The wet meadow is invaded by *Myrica* and *Cornus amomum*, these species, together with some young *Alnus*, forming an advance zone containing most of the secondary species. This zone is gradually subjugated by the *Alnus* consocies.

There are two conspicuous aspects in the formation; one determined in mid-summer by the *Cornus amomum*, and the other in early autumn by the *Solidago canadensis* society.

The *Ulmus-Acer* Formation.

The *Alnus incana* thickets are being invaded by the *Ulmus-Acer* formation, which is here essentially as described for the preceding succession, so that no further discussion of this formation need be here given.

The four ponds — Niagara Pond, Yellow Bass Pond, Grave-Yard Pond, and Big Pond — each have large areas of the various stages of the succession now under consideration, especially the rush vegetation — *Scirpus* formation; and the reed and cat-tail marsh — *Phragmites-Typha* formation. The area dominated later in the season by the wild rice, *Zizania aquatica* society, is especially large in these ponds, excepting Big Pond, where somewhat more of the total area is taken up by other formations. The shores of these ponds present various phases of the two shrub-formations, but have mainly the *Rhus-Alnus* formation. The shores towards the north and east sides of Yellow Pond and Niagara Pond are more sandy and the formations are there practically identical with those around the ponds and lagoons to the north and east.

The Cove Habitat.

The Cove Habitat comprises sheltered portions of the bay with little or no current. The vegetation near the shore is that of the Marsh Habitat, but in deeper water, one and one-half to two feet, the *Scirpus* formation is absent, its place being mainly taken by pond formations. The structure of the vegetation is usually more or less of a mixture of pond and marsh associations, the quieter water being occupied by the pond-plants. The typical cove vegetation at Presque Isle is essentially as follows:

(*a*) *Chara* formation,
(*b*) *Potamogeton* formation,
(*c*) *Castalia-Nymphæa* formation,
(*d*) *Phragmites-Typha* formation,
(*e*) *Rhus-Alnus* formation,
(*f*) *Ulmus-Acer* formation.

Owing to the lack of proper facilities for the work no extended

study was made of the formations occupying the deeper waters of the coves, but from a couple of tours in a rowboat and from such studies as could be made from shore it was seen that the *Chara* formation is present in the deeper waters, extending beyond the *Potamogeton* formation, and that the *Potamogeton* formation is by far the most important one in the cove. Its structure is typically as follows:

Facies. —
Potamogeton natans, *Potamogeton heterophyllus*.

Principal Species. —
Utricularia vulgaris.

Secondary Species. —
Naias flexilis, *Philotria canadensis*,
Vallisneria spiralis, *Potamogeton foliosus*,
Potamogeton lonchites, *Potamogeton foliosus niagarensis*,
Potamogeton zizii, *Potamogeton lucens*,
Potamogeton pectinatus, *Bidens beckii*,
Myriophyllum spicatum, *Utricularia intermedia*.

The genus *Potamogeton* comprises the main bulk of the vegetation visible at the surface of the water, although *Naias* and *Philotria* are quite abundant below the surface. In the quieter and more sheltered coves the *Utricularia vulgaris* aspect is quite pronounced during July and August, the society disappearing largely by the time the *Potamogetons* have attained their best development. The exact status of the various species of *Potamogeton* in the structure of the formation proved to be an extremely difficult problem, but it is believed that the above classification is as exact as can be made, without establishing quadrats and laboriously determining the structure plant by plant — a very difficult thing to accomplish in such a habitat.

The *Castalia-Nymphæa* Formation.

The *Castalia-Nymphæa* formation is not so well developed in the coves as one would be led to suspect from the general characters of the habitat — in fact the suspicion at once arises that abnormal conditions may have been brought about by the continual search for flowers on the part of the people of Erie, just across the bay. In the more inaccessible ponds of the peninsula the formation appears to be more nearly normal. The formation, as it appears where best developed in a cove to the southwest of the Chimney Ponds, presents the following structure:

Facies. —
Castalia tuberosa, *Nymphæa advena*.

Secondary Species. —
Pontederia cordata, *Potamogeton natans*,
Potamogeton lonchites, *Potamogeton heterophyllus*,
Myriophyllum spicatum, *Utricularia intermedia*,
Utricularia vulgaris, *Sagittaria latifolia*,
Naias flexilis, *Philotria canadensis*.

Wherever the *Phragmites-Typha* formation, or in some cases even the *Scirpus* formation, has been disturbed, as in making an opening through the vegetation for a passage to a boat-landing, the *Castalia-Nymphæa* formation, at least the secondary species, will soon come in. The formation in this case is of course to be regarded as a secondary formation, and, if left undisturbed, would soon give place again to the normal formation. Cove formations very similar to those at Presque Isle are to be seen highly developed along the Sandusky Bay side of Cedar Point, Ohio, but there the *Castalia-Nymphæa* is more important as a constituent of the vegetation, ranking relatively as high as does the *Phragmites-Typha* formation.[82]

The *Phragmites-Typha* Formation.

This formation in a sheltered cove is usually either dominated or entirely replaced by the *Typha latifolia* consocies, the latter forming a very dense vegetation, giving but scant opportunity for the development of secondary species. This formation builds up a humus-soil which is finally invaded by the following shrub-formation.

The *Rhus-Alnus* Formation.

On account of the rapid accumulation of humus by the *Typha* zone that zone has a distinct slope from the outer to the inner edge, and is comparatively narrow, being followed closely by the *Rhus-Alnus* formation without the occurrence of an intervening *Cladium-Calamagrostis* zone. The *Rhus-Alnus* zone is much the same as in the marsh habitat, the *Alnus incana* consocies predominating. Among the secondary species are here to be included *Hibiscus moscheutos* and *Sambucus canadensis*. This formation is ultimately followed by the *Ulmus-Acer* formation, as described for the marsh habitat.

[82] Jennings, O. E. "An Ecological Classification of the Vegetation of Cedar Point." *l. c.*, pp. 334–338.

The Driftwood Habitat.

The region included in this habitat is the eastern shore of Misery Bay, extending from the U. S. North Pier to the mouth of Niagara Pond. The shore is here fronted by an old line of wooden piers which serve to some extent to protect the shore from the force of the waves. The sandy bottom slopes gradually from the shore, at least inside the line of piers, and the westerly winds have piled here much driftwood and floating rubbish of all sorts.

The sand-plain extends almost to the water's edge along the southern two-thirds of this shore, but along the northern third the *Prunus* forest formation has occupied the corresponding area. With the decay of the driftwood much organic matter is mixed with the sand, which is continually being blown over from the sand-plain, and the result is a dark-colored sandy loam with a very high humic content. The structure of the vegetation along this shore is essentially as follows:

(*a*) *Potamogeton* Formation.
(*b*) *Typha-Scirpus* Formation.
(*c*) *Sagittaria-Alisma* Formation,
(*d*) *Salix-discolor-lucida* Formation (or the *Cladium-Calamagrostis* Formation).

There is comparatively little of the *Potamogeton* formation inside of the old piles along shore, the water being for the most part quite shallow, and the *Scirpus-Typha* formation taking up most of the area. There is some indication of a change towards the *Phragmites-Typha* formation as the entrance to Niagara Pond is approached—some *Zizania* making its appearance, but most of the zone is clearly to be referred to the same formation which is to be seen in the nearby ponds and lagoons, there being, however, more *Typha*. The habitat of this formation is probably very little affected by the accumulation of humus from the decay of the driftwood, and the protection afforded from the active surf by the line of old piles makes the habitat very similar to that of the recently formed ponds and lagoons along the northeastern extremity of the peninsula.

The *Sagittaria-Alisma* Formation.

The character of this formation is chiefly determined by the accumulation of humus derived from the driftwood. The plants composing this formation consist of species usually associated with rich alluvial deposits of mud, the composition of the formation being essentially as follows:

Facies.—
Sagittaria latifolia, *Alisma plantago-aquatica.*

Secondary Species.—
Cardamine pennsylvanica, *Radicula palustris hispida*,
Salix sp. (seedlings), *Naumbergia thyrsiflora*,
Isnarda palustris, *Stachys palustris*,
Dulichium arundinaceum, *Cicuta bulbifera*,
Carex comosa, *Persicaria laurina*,
Persicaria incarnata, *Rumex altissimus*.

This formation extends from slightly above water on the shore to a depth of five or six inches, it being on rare occasions entirely out of the water, due to a falling of the water-level in the bay, and often being inundated in times of higher water.

The *Salix discolor-lucida* Formation.

The *Salix discolor-lucida* formation is at its best at about the middle of the driftwood habitat opposite the widest part of Horse-shoe Pond. In places the shore becomes more xerophytic and the drift-beach, thickly strewn with débris, supports *Xanthium* and *Argentina*, but no *Cakile*. Towards the entrance to Niagara Pond there is a narrow zone of the *Cladium-Calamagrostis* formation backed by an *Alnus* thicket with *Cornus stolonifera* and *Cornus amomum* at its outer edge, but this thicket is being killed out by the shading effects of the *Prunus-Acer* formation just behind it.

The typical *Salix discolor-lucida* formation as exhibited along the driftwood habitat of Presque Isle is as follows:

Facies.—
Salix discolor, *Salix lucida.*

Secondary Species.—
Salix cordata, *Radicula palustris hispida*,
Persicaria laurina, *Cardamine pennsylvanica*,
Argentina anserina, *Carex comosa*,
Xanthium commune, *Erigeron ramosus.*

This formation differs here but little from its corresponding station near the Head, excepting in the greater prominence of *Salix lucida*. The latter species is here more prominent than is *Salix cordata* and is extending itself out into the *Sagittaria-Alisma* formation in little islands and peninsulas, where the driftwood and sand have risen above

the water. Several of the secondary species are often able to successfully complete their growth upon decaying driftwood floating upon the water near the shore. Among these species may be mentioned *Radicula palustris hispida*, *Cardamine pennsylvanica*, and *Erigeron ramosus*.

It is very likely that this formation will eventually fill up the space out to the old piles and will be followed by an *Alnus* thicket. That the formation has not made more progress in the past has doubtless been due to the proximity of the lake to the east and the consequent drifting of sand, but with the recent closing in of the Horse-shoe Pond on the east, and the further advance of the shore-line beyond, the driftwood habitat will be farther and farther removed from these xerophytic influences, and will approach more and more the conditions of a hydrophytic muck-swamp, passing eventually into the *Ulmus-Acer* stage.

SECONDARY SUCCESSIONS.

Presque Isle presents but two secondary successions — the Burn Succession and the Cultural or Pasture Succession.

The Burn Succession.

Examples of this succession are to be seen in small areas immediately to the south of the east end of Long Ridge and along the ridge to the south of Ridge Pond. The first mentioned area evidently supported in part a mixed formation derived from the *Rhus-Alnus* thicket and the *Prunus-Acer* forest formations, and in part supported a patch of the *Sorghastrum nutans* consocies. During the year following the denudation of the habitat many shoots arose from the uninjured roots of the *Rhus typhina* and a few shoots of *Myrica caroliniana* appeared. The habitat will likely soon support a well-developed *Rhus typhina* thicket.

Where the habitat of the *Sorghastrum nutans* consocies had been burned over, apparently but little damage had been done. The clumps had not been burned so low as to kill the roots entirely and the grass, although thinned out considerably, appeared again the following season in sufficient abundance to completely dominate the area. Most of the normal secondary species were also present in reduced numbers.

To the south of Ridge Pond it appears that certain portions of the sandy ridge had been cleared and burned in connection with the building of the board-walk running over to the lighthouse. The vegetation of this area now consists of a secondary formation which may be termed the

Populus-Rhus Secondary Formation.

This formation is considerably mixed with various adjacent formations, but its general structure is as follows:

Facies. —

Populus tremuloides,	*Rhus typhina*.

Secondary Species. —

Andropogon furcatus,	*Panicum scribnerianum*,
Danthonia spicata,	*Agrostis hyemalis*,
Poa triflora,	*Poa compressa*,
Rubus allegheniensis,	*Rubus villosus*,
Prunus virginiana,	*Prunus serotina*,
Celastrus scandens,	*Acer saccharinum*,
Koellia verticillata,	*Gnaphalium polycephalum*,
Gnaphalium uliginosum,	*Pinus strobus*,
Myrica carolinensis,	*Quercus borealis*,
Quercus velutina,	*Sassafras sassafras*,
Meibomia dillenii,	*Prunus pennsylvanica*,
Prunus pumila,	*Tilia americana*,
Leptilon canadense,	*Artemisia canadensis*,

Erechtites hieracifolia.

No species among the long list of secondary species could with propriety be designated as "principal species." The larger part of the vegetation is comprised in the *Populus tremuloides* consocies, this being of much larger extent than is the *Rhus typhina* consocies. The two facies are rarely found closely associated, but are in separate clumps, or in the absence of *Rhus*, the *Populus* occurs singly, scattered about among the secondary species.

After the normal vegetation was destroyed, there was evidently considerable shifting of the sand by the wind, and some dune building, this latter process leading to the invasion of the area by certain dune-plants, some of which (*Prunus pumila*, *Andropogon furcatus*) still persist among the so-called secondary species.

As the matter now stands with reference to the secondary species the *Populus-Rhus* formation is being invaded by various formations of both the sand-plain, the ridge, and the dune successions. There are,

however, a considerable number of *Quercus velutina* trees now in evidence, mostly small as yet, so that the habitat will in the not distant future pass into the *Quercus velutina* forest formation, and thus be restored to its proper position with respect to the adjacent normal successions.

The Pasture Succession.

The pasture succession (cultural succession) is due, indirectly, to human agency by the pasturing of cattle near the U. S. Life Saving Station (see map). The continual trampling of the normal vegetation into the sand has resulted in the addition of humus to the soil, thus enriching it, and at the same time has made the soil more compact, with a greater and more uniform water-holding power, furnishing thus suitable edaphic conditions for the invasion of certain ruderal plants, common to such situations, as well as for certain mesophytic grasses, which under constant grazing have formed in places a compact and vigorous turf.

The structure of this formation as here presented is as follows:

Facies. —

Poa pratensis.

Secondary Species. —

Poa triflora,	*Poa compressa,*
Salix nigra,	*Trifolium repens,*
Trifolium pratense,	*Ranunculus abortivus,*
Plantago major,	*Plantago lanceolatus,*
Cyperus rivularis,	*Cerastium vulgatum,*
Moehringia lateriflora,	*Medicago lupulina,*
Onagra biennis,	*Taraxacum taraxacum,*
Erigeron philadelphicus,	*Carduus arvensis,*

Achillea millefolium.

The total area occupied by this formation is small, and at one-fourth of a mile from the Life Saving Station it has disappeared entirely. None of the species could be regarded as important enough to merit the rank of principal species, being much scattered and very few in number of individuals.

PHYTOGEOGRAPHIC RELATIONSHIPS OF THE FLORA OF PRESQUE ISLE.

The phytogeographic relationships of the flora of Presque Isle are comparatively rather complex. The vegetation of the mainland about

Erie, classified according to Merriam's system of life-zones,[83] belongs typically to the Alleghanian area of the transition zone; the northern or southern elements dominating in limited areas, the ecological conditions of which approach more nearly to the boreal or austral zones respectively. The escarpment at the head of Presque Isle is more than eighty feet in height, and, although almost perpendicular, it is quite heavily wooded. Its forest is typically a hemlock-birch formation with secondary species of *Ostrya*, red maple, beech, and *Tilia*. The shrubs are *Sambucus racemosa*, *Rubus odoratus*, and *Hamamelis*, while the herbaceous layer consists mainly of various mosses, *Adiantum pedatum*, and *Dryopteris spinulosa*. The distinct tendency of the cliff vegetation here is Canadian as to the trees, but Alleghanian as to the under vegetation.

As to the mainland back of the escarpment the forest is about equally composed of hemlock, black and red oak, and chestnut, with considerable *Magnolia acuminata*, *Liriodendron*, and *Prunus serotina*, and lesser numbers of white ash and *Betula lutea*. This forest, as to the trees, is thus composed about equally of northern and southern (boreal and austral) species, and may thus be regarded as typical Alleghanian (eastern transition). The undergrowth here is typically composed of Alleghanian species, but there are a few species, the ranges of which extend far to the south, reaching the gulf coast or even the tropical region.

The flora of Presque Isle comprises at least 430 ferns and seed-plants, and, grouping these in a general manner according to Merriam's life-zones, there are to be distinguished three main groups as follows:

A. Species the range of which is northern, Canadian, or Alleghanian, or extending over more or less of both areas. Total, 115 species.

Typical representatives of this group are:

Viola rotundifolia,	*Viola rafinesquii,*
Lepargyræa canadensis,	*Arctostaphylos uva-ursi,*
Oxycoccus macrocarpus,	*Trientalis americanus,*
Menyanthes trifoliata,	*Gerardia paupercula,*
Viburnum acerifolium,	*Viburnum dentatum,*

[83] Merriam, C. H. "A Provisional List of Canadian Plants — The Vertebrates of the Adirondack Mountain Region." *Trans. Linnæan Soc. N. Y.*, I: 26, Dec., 1882: and "Life Zones and Crop Zones of the United States." Div. Biol. Survey, U. S. Dept. of Agriculture, Bull. 10: 1–79, 1898.

Lobelia kalmii, *Hieracium canadense*,
Aster polyphyllus, *Gnaphalium decurrens*,
Artemisia canadensis, *Argentina anserina*,
Prunus pumila, *Prunus pennsylvanica*,
Pinus strobus.

B. Species the range of which is southern — Carolinian, or extending also over other areas of the austral (austroriparian or gulf strip). Total 42 species.

Typical representatives of this group are:

Lycopodium alopecuroides, *Hemicarpha micrantha*,
Magnolia acuminata, *Liriodendron tulipifera*,
Blephariglottis peramœna, *Ptelea trifoliata*,
Hypericum drummondii, *Sabbatia angularis*,
Asclepias tuberosa, *Lithospermum gmelini*,
Lycopus rubellus, *Galium pilosum*,
Gnaphalium purpureum, *Sassafras sassafras*,
Nyssa sylvatica.

C. Species the range of which with respect to the position of Presque Isle is neither definitely northern nor southern. Species generally ranging over both Carolinian and Alleghanian areas. Total, 283 species.

From the above grouping it appears that, taken as a whole, the flora of Presque Isle is more distinctly northern than southern, and in a general way may be termed Alleghanian, although the greater majority of the species are not closely restricted to either class. It is of interest to note in this connection that Todd, in his studies on the Birds of Erie and Presque Isle,[84] says: "The region under consideration [Presque Isle] may safely be considered as included within the Alleghanian Fauna, although with a slight admixture of the Carolinian element."

Transeau has pointed out that in eastern North America there may be distinguished four great forest centers, each center having peculiar to it a forest the species of which attain there their best development, thinning out from the region in all directions.[85] These centers are: "(1) the Northeastern Conifer Forest, centering in the St. Lawrence Basin, (2) the Deciduous Forest, centering in the lower Ohio basin and Piedmont

[84] Todd, W. E. Clyde. "The Birds of Erie and Presque Isle, Erie County, Pennsylvania." ANNALS CARNEGIE MUSEUM, II: 497, 1904.

[85] Transeau, E. N. "Forest Centers of Eastern America." *Am. Nat.*, 39: 875–889, 1905.

Plateau, (3) the Southeastern Conifer Forest, centering in the south Atlantic and Gulf coastal plain, and (4) the Insular Tropical Forest of the southern part of the Florida peninsula, centering in the West Indies." As far as Presque Isle is concerned the first two centers alone need to be considered.

The Northeastern Conifer Forest center, at least as far as the woody species are concerned, practically includes the eastern part of Merriam's Canadian Area together with the northern part of his Alleghanian Area, and in a general way this forest center may be regarded as the center for our first group of Presque Isle species (A), including altogether one hundred and fifteen species.

Our second group (B) of forty-two Presque Isle species is very closely co-extensive with Transeau's Deciduous Forest center, including thus the Carolinian Area and the southern extension of Merriam's Alleghanian Area, thinning out in all directions from this region.

It is thus to be seen that the region in which Presque Isle is located is more or less intermediate in geographical position between these two centers, but the true relations of the different elements as entering into the vegetation of Presque Isle are most evident when the formations and successions are individually considered. The intermediate position of Presque Isle is such that variations in the local ecological conditions of the soil, wind-exposure, etc., may swing the habitat into either the one or the other forest center (climatic or geographic) while in the more permanently intermediate habitats there may be a vegetation composed in part of derivatives from both centers; or, from historical causes the one or the other forest center may even there predominate.

In general it may be stated that on Presque Isle, proceeding from the physiographically youngest habitat to the oldest, the relationship of the corresponding vegetation swings gradually from the Northeastern Conifer Forest to the Deciduous Forest center, and on the northern side of the peninsula, with greater exposure and coarser soil particles, the northern element persists longer than on the southern side, where these conditions are less pronounced.

Transeau[86] has shown that the great forest centers are correlated very closely with certain "rainfall-evaporation ratios," the ratio of total rainfall being largely dependent upon the same conditions of temperature, wind velocity, relative humidity, etc., which most largely in-

[86] Transeau, E. N. *l. c.*, 883–886.

fluence transpiration. Transeau found that in a general way, "The southeastern area where the rainfall is from 100–110 per cent. of the evaporation, corresponds to the region of the Deciduous Forest center," and that in the Southern Appalachians at least, the region with the ratio above 110 per cent. coincides with the southern extension of the Northeastern Conifer Forest, while the forest center in the St. Lawrence basin is marked by ratios above 100 per cent.

The ratio for the city of Erie is not less than 110 per cent., but the instruments of the U. S. Weather Bureau Station there are about 180 feet above Lake Erie and it is probable that the ratio for Presque Isle, but a few feet above the lake and within reach of its more immediate effects upon humidity, temperature, etc., would be found to be considerably higher. However the ratio would vary greatly between the various habitats on the peninsula itself; as, for instance, between the interior of the sand-plain, with its loose sand fully exposed to wind and insolation, and the interior of the black oak forest, with its shaded, humus-covered soil, the temperature of which never presents the rapid and extreme variations of the surface of the sand-plain. The rainfall-evaporation ratio would probably be below 100 for the sand-plain and perhaps a careful instrumental determination of the factors would show that there is a constantly increasing ratio from the sand-plain to the black oak forest, which could be correlated with the shifting of the relationship of the respective formations from the northeastern conifer forest to the deciduous forest.

The lower and drift beaches of Presque Isle are under the equalizing influences of the water to such an extent that they are inhabited by a formation found in similar habitats almost throughout North Temperate America, but removed from the more immediately modifying influences of the water, the sand-plain, with its sterile, porous, wind-exposed soil, supports a formation including several distinctly northern species: *Artemisia canadensis*, *Lathyrus maritimus*, or, around the lagoons and ponds in the sand-plain, *Triglochin palustris*, *Carex aquatilis*, *C. gronovii*, *C. œderi pumila* and *C. canescens*, *Juncus balticus*, *J. articulatus*, *Salix syrticola*, *Hypericum boreale*, etc., or, on the dunes in the sand-plain, *Prunus pumila*.

With the advent of considerable numbers of woody species upon the sand-plain its southern portion is occupied by the *Myrica* thicket, which must be regarded as having southern affinities, while the northern portion of the sand-plain is occupied by the *Arctostaphylos-Juniperus* heath, a distinctly northern formation. The *Myrica* thicket is soon superseded by the *Prunus serotina* forest, which in its turn gives way to the *Quercus velutina* forest, both formations being distinctly southern and related to the deciduous forest. The heath stage is succeeded by the *Pinus strobus* forest, distinctly northern, but this is eventually displaced by the black oak forest, distinctly southern.

In the Dune-Thicket-Forest Succession the initial stage may be distinctly northern, as in the *Ammophila* and *Prunus pumila* dunes, or more southern, as in the *Populus* and *Andropogon* dunes. In either case these dunes may towards the southern side of the peninsula pass into the *Toxicodendron* thicket and the *Prunus serotina* forest, both related to the deciduous forest center, or towards the northern side of the peninsula they may pass into the *Arctostaphylos-Juniperus* heath and then into the *Pinus strobus* forest, both with northern affinities. The climax forest for the succession is, however, the *Quercus velutina* forest, this being distinctly related to the deciduous forest center.

In the Lagoon-Marsh-Thicket-Forest Succession the more hydrophilous formations on Presque Isle consist of species of wide distribution, but in the zoned formations on the banks of the lagoon or pond there may be seen tendencies towards either the one or the other forest center. Thus, in the first three stages of the succession a considerable number of the species are northern — *Triglochin palustris*, *Carex œderi pumila*, *Juncus balticus*, *J. articulatus*, *J. alpinus insignis*, *J. nodosus*, etc.

With the growth of the outer *Populus-Salix* zone and the advent of an inner shrub-zone around the lagoons, together with the leaving of the lagoons farther inland with the onward growth of the peninsula, the direct exposure to high winds becomes less and less at the same time that species with southern relationships become more prominent. However, the wet meadow formation, *Cladium-Calamagrostis* formation, and its outer shrub-zones, the *Myrica-Salix* and *Rhus-Alnus* formations, are quite distinctly northern, and the wet meadow may be invaded and occupied by other typically northern formations, as the *Fragaria-Polytrichum* and the *Sphagnum-Oxycoccus* formations. The climax stages of the succession, however, are more southern than northern, the final *Ulmus-Acer* forest belonging clearly to the deciduous forest center.

The burn succession also apparently begins with formations belonging

to the northeastern conifer forest and ends in the black oak forest with more southern relationships. Fire by removing the organic matter brings the habitat on Presque Isle back to practically sand-plain conditions, and so invites invasion by species from the northeastern conifer forest, but with the accumulation of humus in the soil and the occupation of the habitat by sheltering vegetation more uniform conditions of moisture and temperature obtain, and there is a gradual reversion on the part of the vegetation to the deciduous forest species.

In considering the invasion of species or associations of species from the one or the other forest center it must be remembered that in the initial stages of the successions on Presque Isle the vegetation is more or less "open," there being considerable unoccupied territory between the individual plants of the formation, competition being therefore reduced to the minimum. The beach-sand plain successions and the dune successions do not really approach "closed" conditions until the advent of the *Prunus serotina* or the *Pinus strobus* forests, while the lagoon succession remains more or less open until about "Stage E."

The comparative rapidity with which the land form of Presque Isle has been extended to the north and east makes necessary upon the part of the plants a corresponding ability to migrate. The disseminules of the plants must in some manner be distributed to a considerable distance from the parent plant, especially in the case of trees, where a number of years must elapse before the attainment of a seed-bearing age.

Of the numerous agents of dissemination three are prominent among the species of the initial stages of the successions occupying the newly-formed land towards the northeastern extremity of the peninsula: (*a*) water, (*b*) wind, and (*c*) animals, mainly birds. Of these agents the first, of course, prevails in the beach formations and in the fringing *Ammophila* dune, although indirectly wind has an important part in this also.

In the sand-plain and in the earlier stages of the lagoon succession wind is evidently the most important agent of dissemination, although for the initial invasion of a species around a lagoon birds are probably the all-important factor. The disseminules of *Juncus*, *Eleocharis*, *Cyperus*, etc., are known to be carried considerable distances adhering to the plumage or sticking in the mud on the feet of water-birds of

various kinds, especially during the migrating season.[87] When once invasion has been accomplished, the formation of zones will rapidly proceed, mainly through the agency of wind.[88] The submerged formations and the formations at the edge of the water will depend to a large extent upon water as an agent of distribution, and in most of these formations vegetative dissemination by means of rootstocks and off-shoots of various kinds is also prominent.

Many of the plants of the sand-plain and its included habitats have disseminules with special adaptations to dispersal by wind: *Populus*, *Salix*, *Solidago*, *Aster*, etc. In other species the small seeds are probably drifted about with the dry sand, or more or less of the whole plant may be undermined and uprooted and drift about, scattering seeds along its path. It is also highly probable that disseminules of several of the sand-plain species and species of the adjoining thickets are blown over the level expanses of crusted snow during winter: *Alnus*, *Rhus*, *Myrica*, *Pinus strobus*, etc. In most of these species the disseminules are more or less persistent until long into the winter.

Deglutition by birds is an important means of distribution of the forest and thicket species, but these species do not thus reach the sand-plain to any considerable extent until the vegetation offers perching facilities. A large number of the species of the forest and thicket formations have fruits eaten by birds, many of the fruits being persistent during the winter months. Among such species may be mentioned *Juniperus*, *Toxicodendron*, *Arctostaphylos*, *Rhus*, *Celastrus*, *Smilax*, *Vitis*, and *Myrica*, while of the less persistent fruits eaten and distributed by birds are such species as *Fragaria*, *Rubus*, *Prunus*, *Unifolium*, *Vagnera*, *Vaccinium*, etc. *Juniperus virginiana* almost invariably first appears on the sand-plain a few feet to the leeward of a cottonwood, where the drupe was deposited by a bird whose perching position was probably determined by the strong wind.

As to the dissemination of the oaks invasion must be due to animal agencies, as no other explanation seems sufficient to explain the appearance of seedlings at considerable distances from trees old enough

[87] Kerner, A. von Marilaun. Trans. by Oliver, F. W. "The Natural History of Plants." Vol. 2: 867–868.

[88] As an instance of probable invasion by means of bird migration may be cited *Hypericum drummondii* which has a distribution from "Va. to Ga., Ill., Iowa, Kansas, and Tex." (Britton, N. L., "Manual," *l. c.*, p. 628), but now occurs in Ashtabula County, Ohio, and at Presque Isle. The minute seeds of this plant might easily be transported long distances in mud adhering to the feet of migrating birds.

to bear fruit. Usually the seedlings are in such a position as would indicate that the acorn had been secreted by bird or animal, as for instance, in the *Arctostaphylos* mat of the heath, where young black oaks are quite numerous at a distance of at least 40 rods from trees old enough to bear acorns. It is well known that the blue jay and the crow subsist largely upon wild fruits and mast during the winter months and probably secrete quantities of larger nuts, acorns, etc., as stores to resort to in cases of scarcity of food.[89] The former bird is an abundant permanent resident of Presque Isle, while the latter is abundant during late fall and early spring, or even remaining on the peninsula in limited numbers during the winter.[90] From this the dissemination of the oaks may be ascribed to these agents, in at least a large measure.

Vegetative dissemination by means of branching rhizomes, offshoots, etc., is very prevalent in the earlier stages of the successions, especially where the soil is loose and the formation is open. Among the more conspicuous examples of this method of dissemination on Presque Isle are: *Panicum*, *Andropogon*, *Ammophila*, *Myrica*, *Linum*, *Aster*, *Solidago*, *Arctostaphylos*, *Juncus*, *Eleocharis*, *Typha*, *Scirpus*, *Vagnera*, *Unifolium*, etc. In the more hydrophytic formations, as mentioned for the inner zones around the lagoon, and also as represented by *Cephalanthus*, *Decodon*, *Castalia*, *Sphagnum*, etc., this method is a very prominent one.

This brief sketch of the methods of dissemination on Presque Isle shows that here, as elsewhere,[91] *water* is the most important agent of dissemination with beach plants; *wind* with xerophytic (dry sand-plain plants), or poöphytic plants (grasses of the sand plain and wet meadow, as *Andropogon* and *Calamagrostis*); and *animals* with hylophytes (forest plants).

A fact to be noted, in connection with the prevailing methods of migration of plants to the new habitats on Presque Isle, is that the species with northern relationships, such, for instance as *Populus*, *Salix*, *Pinus*, *Arctostaphylos*, *Triglochin palustris*, *Carex œderi pumila*, *Juncus balticus*, etc., have, as a rule, a much greater ability to

[89] Barrows, W. B., and Schwartz, E. A. "The Common Crow of the United States." Div. Ornithology and Mammalogy, U. S. Dept. Agr. Bull. 6: 79–87, 1895; and Beal, F. E. L. "Some Common Birds in Their Relation to Agriculture." U. S. Dept. Agr., Farmers' Bulletin No. 54: 14–17, 1898.

[90] Todd, W. E. C. *l. c.*, pp. 565–566.

[91] Clements, F. S. *l. c.*, p. 218.

migrate, both as to distance covered and as to numbers of migrating disseminules, than do species with more southern relationships, as, for instance, *Quercus velutina*, *Ulmus americana*, *Acer saccharinum*, etc., so that for historical reasons, as well as for reasons of adaptation to a more northern environment, the earlier stages in most of the successions are more largely related to the northeastern conifer forest center, or at least are more northern in their relationship.

A SYSTEMATIC CATALOGUE OF THE FERNS AND FLOWERING PLANTS OF PRESQUE ISLE, ERIE COUNTY, PENNSYLVANIA.

OPHIOGLOSSACEÆ.

Ophioglossum vulgatum Linnæus.
Botrychium obliquum Muhlenberg.
Botrychium virginianum (Linnæus) Swartz.

OSMUNDACEÆ.

Osmunda claytoniana Linnæus.
Osmunda spectabilis Willdenow.

POLYPODIACEÆ.

Onoclea sensibilis Linnæus.
Woodsia obtusa (Sprengel) Torrey.
Dryopteris boottii (Tuckerman) Underwood.
Dryopteris spinulosa (Retzius) Kuntze.
Dryopteris spinulosa dilatata (Hoffmansegg) Underwood.
Dryopteris spinulosa intermedia (Willdenow) Underwood.
Dryopteris thelypteris (Linnæus) A. Gray.
Polystichum acrostichoides (Michaux) Schott.

EQUISETACEÆ.

Equisetum arvense Linnæus.
Equisetum hyemale Linnæus.
Equisetum sylvaticum variegatum Schleicher.
"Erie, Presque Isle, Garber." [92]

LYCOPODIACEÆ.

Lycopodium alopecuroides Linnæus.
Gustave Guttenberg, 1879. Specimens in Carnegie Museum Herbarium.

[92] Porter, T. C. "Catalogue of the Bryophyta and Pteridophyta found in Pennsylvania." Boston, 1904.

Lycopodium clavatum Linnæus.
Lycopodium complanatum Linnæus.
Lycopodium lucidulum Michaux.
Lycopodium obscurum Linnæus.

ISOETACEÆ.

Isoetes echinospora braunii (Durieu) Engelmann.
A. P. Garber, July 28, 1868. Specimens in Carnegie Museum Herbarium.

PINACEÆ.

Pinus strobus Linnæus.
Pinus virginiana Miller.
Near the Head and evidently planted by U. S. Government.
Tsuga canadensis (Linnæus) Carriere.
Juniperus virginiana Linnæus.

TYPHACEÆ.

Typha latifolia Linnæus.

SPARGANIACEÆ.

Sparganium eurycarpum Engelmann.
Sparganium simplex angustifolium (Michaux) Engelmann.
Gustave Guttenberg, July 9, 1879. Specimens in Carnegie Museum Herbarium.
Sparganium minimum Fries.
Gustave Guttenberg, Aug. 1, 1880. Specimens in Carnegie Museum Herbarium.

NAIADACEÆ.

Potamogeton natans Linnæus.
Potamogeton lonchites Tuckermann.
Potamogeton heterophyllus Schreber.
Potamogeton heterophyllus graminifolius (Fries) Morong.
"Erie, Presque Isle."[93]
Potamogeton zizii Roth.
Potamogeton lucens Linnæus.
Gustave Guttenberg, July 9, 1879. Carnegie Museum Herbarium.
Potamogeton perfoliatus richardsonii A. Bennett.
Gustave Guttenberg, Aug. 10, 1880. Carnegie Museum Herbarium.

[93] Porter, T. C. "Flora of Pennsylvania." Boston, 1903.

Potamogeton foliosus Rafinesque.
Potamogeton foliosus niagarensis (Tuckermann) Morong.
Potamogeton pectinatus Linnæus.
Naias flexilis (Willdenow) Roemer & Schultes.

SCHEUCHZERIACEÆ.

Triglochin palustris Linnæus.

ALISMACEÆ.

Alisma plantago-aquatica Linnæus.
Sagittaria latifolia Willdenow.
Sagittaria rigida Pursh.
Sagittaria graminea Michaux.
Gustave Guttenberg, July 9, 1879. Carnegie Museum Herbarium.

HYDROCHARITACEÆ.

Philotria canadensis (Michaux) Britton.
Vallisneria spiralis Linnæus.

GRAMINEÆ.

Andropogon furcatus Muhlenberg.
Sorghastrum nutans (Linnæus) Nash.
Panicum virgatum Linnæus.
Panicum scribnerianum Nash.
Cenchrus carolinianus Walter.
Zizania aquatica Linnæus.
Oryzopsis asperifolia Michaux.
Gustave Guttenberg, "Big Bend," May 8, 1880. Carnegie Museum Herbarium.
Muhlenbergia mexicana (Linnæus) Trinius.
Sporobolus cryptandrus (Torrey) A. Gray.
Gustave Guttenberg, "Misery Bay," Sept. 26, 1879. Carnegie Museum Herbarium.
Agrostis hyemalis (Walter) Britton, Sterns & Poggenberg.
Calamagrostis canadensis (Michaux) Beauvois.
Ammophila arenaria (Linnæus) Link.
Avena sativa Linnæus.
Fugitive along shore of Presque Isle Bay.
Danthonia spicata (Linnæus) Beauvois.
Gustave Guttenberg, July 10, 1879. Carnegie Museum Herbarium.

Phragmites phragmites (Linnæus) Karsten.
Triplasis purpurea (Walter) Chapman.
Eragrostis purshii Schrader.
Poa triflora Gilibert.
Poa pratensis Linnæus.
Poa compressa Linnæus.
Panicularia nervata (Willdenow) Kuntze.
Gustave Guttenberg, "Lower Lighthouse," June 12, 1879. Carnegie Museum Herbarium.
Festuca octoflora Walter.
Elymus canadensis Linnæus.

CYPERACEÆ.

Hemicarpha micrantha (Vahl) Britton.
Dulichium arundinaceum (Linnæus) Britton.
Cyperus rivularis Kunth.
Cyperus schweinitzii Torrey.
Cyperus engelmanni Steudel.
Gustave Guttenberg, Aug. 12, 1879. Carnegie Museum Herbarium.
Cyperus strigosus Linnæus.
Cyperus filiculmis Vahl.
Cyperus houghtonii Torrey.
Eriophorum gracile Roth.
Scirpus pauciflorus Lightfoot.
Scirpus subterminalis Torrey.
Gustave Guttenberg, 1879. Carnegie Museum Herbarium.
Scirpus smithii A. Gray.
Gustave Guttenberg, Aug. 12, 1879. Carnegie Museum Herbarium.
Scirpus americanus Persoon.
Scirpus torreyi Olney.
Scirpus validus Vahl.
Scirpus fluviatilis (Torrey) A Gray.
Scirpus atrovirens Muhlenberg.
Scirpus cyperinus (Linnæus) Karsten.
Eleocharis quadrangulata (Michaux) Roemer & Schultes.
Eleocharis olivacea Torrey.
Eleocharis obtusa Schultes.
J. A. Shafer, Sept. 9–11, 1900. Carnegie Museum Herbarium.
Eleocharis palustris (Linnæus) Roemer & Schultes.

Eleocharis palustris glaucescens (Willdenow) A. Gray.
Eleocharis acicularis (Linnæus) Roemer & Schultes.
Eleocharis acuminata (Muhlenberg) Nees.
Eleocharis ovata (Roth) Roemer & Schultes.
Fimbristylis autumnalis (Linnæus) Roemer & Schultes.
Stenophyllus capillaris (Linnæus) Britton.
Cladium mariscoides (Muhlenberg) Torrey.
Scleria verticillata Muhlenberg.
Carex lupulina Muhlenberg.
Carex schweinitzii Dewey.
Gustave Guttenberg, "Crystal Point," June 9, 1880. Carnegie Museum Herbarium.
Carex hystricina Muhlenberg.
Carex pseudo-cyperus Linnæus.
Carex comosa Boott.
Carex scabrata Schweinitz.
Carex lanuginosa Michaux.
Carex filiformis Linnæus.
Carex stricta Lamarck.
Gustave Guttenberg, May 30, 1879. Carnegie Museum Herbarium.
Carex stricta angustata (Boott) Bailey.
Carex aquatilis Wahlenberg.
Carex goodenovii J. Gay.
Gustave Guttenberg, July 9, 1879. Carnegie Museum Herbarium.
Carex prasina Wahlenberg.
Carex virescens Muhlenberg.
Carex arctata Boott.
Carex œderi pumila (Cosson & Germain) Fernald.
Carex laxiflora varians Bailey.
Carex digitalis Willdenow.
Carex aurea Nuttall.
"Erie, Presque Isle."[94]
Carex varia Muhlenberg.
Carex communis Bailey.
Carex umbellata Schkuhr.
Carex sartwellii Dewey.
"Erie, Presque Isle."[94]
Carex muhlenbergii Schkuhr.

[94] Porter, T. C. *l. c.*, p. 67.

Carex canescens Linnæus.
Carex scoparia Schkuhr.

LEMNACEÆ.

Lemna minor Linnæus.

PONTEDERIACEÆ.

Heteranthera dubia (Jacquin) MacMillan.
Pontederia cordata Linnæus.

JUNCACEÆ.

Juncus balticus littoralis Engelmann.
Juncus tenuis Willdenow.
Juncus dudleyi Wiegand.
Juncus articulatus Linnæus.
Juncus alpinus insignis Fries.
Juncus nodosus Linnæus.
Juncus torreyi Coville.
Juncus scirpoides Lamarck.
Juncus brachycephalus (Engelmann) Buchenau.
Juncus canadensis J. Gay.

CONVALLARIACEÆ.

Vagnera racemosa (Linnæus) Morong.
Vagnera stellata (Linnæus) Morong.
Unifolium canadense (Desfontaine) Greene.
Uvularia perfoliata Linnæus.
Salomonia biflora (Walter) Farwell.
Salomonia commutata (Roemer & Schultes) Farwell.

TRILLIACEÆ.

Trillium erectum Linnæus.

SMILACEÆ.

Smilax herbacea Linnæus.

IRIDACEÆ.

Iris versicolor Linnæus.

ORCHIDACEÆ.

Cypripedium acaule Aiton.
Perularia flava (Linnæus) Farwell.
Lysias orbiculata (Pursh) Rydberg.

Lysias hookeriana (A. Gray) Rydberg.
Blephariglottis peramæna (A. Gray) Rydberg.
Ibidium incurvum Jennings.[95]
Ibidium strictum (Rydberg) House.
Epipactis pubescens (Willdenow) A. A. Eaton.
Leptorchis læselii (Linnæus) MacMillan.
Leptorchis liliifolia (Linnæus) Kuntze.
Corallorhiza maculata Rafinesque.

Gustave Guttenberg, July 9, 1879. Carnegie Museum Herbarium.

SALICACEÆ.

Populus alba Linnæus.
Populus tremuloides Michaux.
Populus deltoides Marshall.
Salix nigra Marshall.
Salix lucida Muhlenberg.
Salix fragilis Linnæus.
Salix fragilis × *alba*.
Salix alba Linnæus.
Salix cordata Muhlenberg.
Salix syrticola Fernald.
Salix discolor Muhlenberg.
Salix eriocephala Michaux.

Gustave Guttenberg, June 26, 1879, "Big Bend." Carnegie Museum Herbarium.

Salix sericea Marshall.

MYRICACEÆ.

Myrica carolinensis Miller.

JUGLANDACEÆ.

Juglans cinerea Linnæus.

BETULACEÆ.

Ostrya virginiana (Miller) K. Koch.
Betula lutea F. A. Michaux.
Alnus incana (Linnæus) Moench.

[95] Jennings, O. E. "A New Species of *Ibidium* (*Gyrostachys*)." ANN. CARNEGIE MUSEUM, 3: 483–486. 1906. The *Ibidium cernuum* reported previously for Presque Isle is evidently *I. incurvum*.

FAGACEÆ.

Quercus rubra Linnæus.
Quercus palustris DuRoi.
Quercus borealis F. A. Michaux. (*Q. ambigua* F. A. Michaux.)
Quercus velutina Lamarck.

(Perhaps some of the specimens referred to the three first named species are here to be regarded as extreme variations of *Q. velutina*.)

ULMACEÆ.

Ulmus americana Linnæus.

URTICACEÆ.

Bœhmeria cylindrica (Linnæus) Swartz.

POLYGONACEÆ.

Rumex acetosella Linnæus.
Rumex verticillatus Linnæus.
Rumex altissimus Wood.
Persicaria fluitans (Eaton) Greene.
Persicaria incarnata (Elliott) Small. (*Polygonum incarnatum* Elliott.)
Persicaria hydropiperoides (Michaux) Small. (*Polygonum hydropiperoides* Michaux.)
Persicaria laurina Greene.[96]
Persicaria punctata (Elliott) Small. (*Polygonum punctatum* Elliott.)
Tracaulon sagittatum (Linnæus) Small. (*Polygonum sagittatum* Linnæus.)
Bilderdykia scandens (Linnæus) Greene. (*Polygonum scandens* Linnæus.)

PHYTOLACCACEÆ.

Phytolacca decandra Linnæus.

CARYOPHYLLACEÆ.

Lychnis alba Miller.
Silene antirrhina Linnæus.
Cerastium vulgatum Linnæus.
Arenaria serpyllifolia Linnæus.
Mœhringia lateriflora (Linnæus) Fenzl.

[96] Greene, E. L. "Certain Polygonaceous Genera." Leaflets, 1:17–50. Jan. 5, 1904.

NYMPHÆACEÆ.

Brasenia schreberi Gmelin.
Nymphæa advena Solander.
Castalia tuberosa (Paine) Greene.

MAGNOLIACEÆ.

Magnolia acuminata Linnæus.
Liriodendron tulipifera Linnæus.

RANUNCULACEÆ.

Actæa alba (Linnæus) Miller.
Anemone cylindrica A. Gray.[97]
Anemone canadensis Linnæus.
Clematis virginiana Linnæus.
Batrachium circinatum (Sibthorp) new combination.
Ranunculus abortivus Linnæus.
Ranunculus pennsylvanicus Linnæus, filius.

LAURACEÆ.

Sassafras sassafras (Linnæus) Karsten.

CRUCIFERÆ.

Radicula palustris hispida (Desvaux) Robinson.
Barbarea barbarea (Linnæus) MacMillan.
Brassica arvensis (Linnæus) Britton, Sterns & Poggenberg.
Brassica campestris Linnæus.
Cakila edentula (Bigelow) Hooker.
Cardamine pennsylvanica Muhlenberg.
Arabis lyrata Linnæus.
Arabia lævigata (Muhlenberg) Poiret.

DROSERACEÆ.

Drosera rotundifolia Linnæus.

PARNASSIACEÆ.

Parnassia caroliniana Michaux.

HAMAMELIDACEÆ.

Hamamelis virginiana Linnæus.

[97] Porter, T. C. *l. c.*, p. 138.

GROSSULARIACEÆ.

Ribes cynosbati Linnæus.
Ribes floridum L'Heritier.

ROSACEÆ.

Spiræa latifolia Borkhausen.
Rubus odoratus Linnæus.
Rubus idæus aculeatissimus C. A. Meyer, Regel & Tiling.
Rubus occidentalis Linnæus.
Rubus allegheniensis Porter.
Rubus davisianus Blanchard.
Rubus procumbens Muhlenberg.
Rubus hispidus Linnæus.
Fragaria americana (Porter) Britton.
Fragaria virginiana Duchesne.
Argentina anserina (Linnæus) Rydberg.
Potentilla monspeliensis Linnæus.
Potentilla paradoxa Nuttall. (Porter's "Flora," p. 170.)
Agrimonia gryposepala Wallroth.
Rosa carolina Linnæus.
Rosa humilis Marshall.

POMACEÆ.

Malus malus (Linnæus) Britton.
Aronia melanocarpa (Michaux) new combination.
Amelanchier canadensis (Linnæus) Medicus.
Amelanchier oblongifolia (Torrey & Gray) Roemer.

DRUPACEÆ.

Prunus americana Marshall.
Prunus pumila Linnæus.
Prunus pennsylvanica Linnæus, filius.
Prunus virginiana Linnæus.
Prunus serotina Ehrhart.

PAPILIONACEÆ.

Lupinus perennis Linnæus.
Medicago lupulina Linnæus.
Melilotus officinalis (Linnæus) Lamarck.
Trifolium pratense Linnæus.
Trifolium hybridum Linnæus.

Trifolium repens Linnæus.
Robinia pseudacacia Linnæus.
Astragalus canadensis Linnæus.
Meibomia dillenii (Darlington) Kuntze.
Meibomia canadensis (Linnæus) Kuntze.
Lespedeza capitata Michaux.
Apios apios (Linnæus) MacMillan.
Phaseolus polystachyus (Linnæus) Britton, Sterns & Poggenburg. (Porter's "Flora," p. 190.)
Strophostyles helvola (Linnæus) Britton.
Lathyrus maritimus Linnæus.
Lathyrus palustris Linnæus.

LINACEÆ.

Linum medium (Planchon) Britton.

RUTACEÆ.

Ptelea trifoliata Linnæus.

POLYGALACEÆ.

Polygala verticillata Linnæus.

EUPHORBIACEÆ.

Euphorbia polygonifolia Linnæus.
Euphorbia helioscopia Linnæus.

ANACARDIACEÆ.

Rhus typhina Linnæus.
Rhus aromatica Aiton.
Toxicodendron pubescens Miller. (*Rhus toxicodendron* Linnæus.)[98]

ILICACEÆ.

Ilex verticillata (Linnæus) A. Gray.
Ilex verticillata cyclophylla Robinson.
Ilex verticillata tenuifolia (Torrey) Watson.

CELASTRACEÆ.

Celastrus scandens Linnæus.

ACERACEÆ.

Acer rubrum Linnæus.
Acer saccharinum Linnæus.

[98] See Greene, E. L. "Segregates of *Rhus*." Leaflets, 1: 114–144. Nov. 24 and Nov. 29, 1905.

BALSAMINACEÆ.

Impatiens biflora Walter.

VITACEÆ.

Vitis æstivalis Michaux.
Vitis bicolor LeConte.
Vitis vulpina Linnæus.
Psedera quinquefolia (Linnæus) Greene.

TILIACEÆ.

Tilia americana Linnæus.

MALVACEÆ.

Hibiscus moscheutos Linnæus.

HYPERICACEÆ.

Hypericum perforatum Linnæus.
Hypericum punctatum Lamarck.
Hypericum boreale (Britton) Bicknell.
Hypericum majus (A. Gray) Britton.
Hypericum canadense Linnæus.
Hypericum drummondii (Greville & Hooker) Torrey & Gray.
Triadenum virginicum (Linnæus) Rafinesque.

CISTACEÆ.

Helianthemum canadense (Linnæus) Michaux.
Lechea villosa Elliott.

VIOLACEÆ.

Viola affinis LeConte.
Viola papilionacea Pursh.
Viola rotundifolia Michaux.
Viola blanda Willdenow.
Viola rafinesquii Greene.

ELÆAGNACEÆ.

Lepargyrea canadensis (Linnæus) Greene.

LYTHRACEÆ.

Decodon verticillatus (Linnæus) Elliott.

ONAGRACEÆ.

Isnarda palustris Linnæus.
Epilobium densum Rafinesque.

Gustave Guttenberg, Aug. 10, 1880. Carnegie Museum Herbarium.

Epilobium coloratum Muhlenberg.
Epilobium adenocaulon Haussknecht.
Onagra biennis (Linnæus) Scopoli.
Onagra oakesiana (A. Gray) Britton.
Kneiffia linearis (Michaux) Spach.

HALORAGIDACEÆ.

Proserpinaca palustris Linnæus.
Myriophyllum spicatum Linnæus.

ARALIACEÆ.

Aralia nudicaulis Linnæus.

UMBELLIFERÆ.

Osmorhiza claytoni (Michaux) Clarke.
Cicuta bulbifera Linnæus.
Daucus carota Linnæus.

CORNACEÆ.

Cornus amomum Miller.
Cornus obliqua Rafinesque.[99]
Cornus baileyi Coulter & Evans.
Cornus stolonifera Michaux.
Cornus paniculata L'Heritier.
Nyssa sylvatica Marshall.

PYROLACEÆ.

Pyrola americana Sweet.
Pyrola elliptica Nuttall.
Pyrola secunda Linnæus.
Chimaphila maculata (Linnæus) Pursh.
Chimaphila umbellata (Linnæus) Nuttall.

MONOTROPACEÆ.

Monotropa uniflora Linnæus.

ERICACEÆ.

Arctostaphylos uva-ursi (Linnæus) Sprengel.

[99] Specimens show all gradations between *C. amomum* and *C. obliqua*.

VACCINIACEÆ.

Vaccinium corymbosum Linnæus.
Vaccinium canadense Richards.
Gustave Guttenberg, 1879. Carnegie Museum Herbarium.
Oxycoccus macrocarpus (Aiton) Persoon.

PRIMULACEÆ.

Lysimachia terrestris (Linnæus) Britton, Sterns & Poggenburg.
Naumbergia thyrsiflora (Linnæus) Duby.
Trientalis americana (Persoon) Pursh.

OLEACEÆ.

Fraxinus americana Linnæus.
Fraxinus nigra Marshall.

GENTIANACEÆ.

Sabbatia angularis (Linnæus) Pursh.
Gentiana andrewsii Grisebach.

MENYANTHACEÆ.

Menyanthes trifoliata Linnæus.

ASCLEPIADACEÆ.

Asclepias syriaca Linnæus.
Asclepias tuberosa Linnæus.

CONVOLVULACEÆ.

Convolvulus sepium Linnæus.

CUSCUTACEÆ.

Cuscuta gronovii Willdenow.

BORAGINACEÆ.

Myosotis laxa Lehmann.
Myosotis arvensis (Linnæus) Lamarck.
Lithospermum gmelini (Michaux) Hitchcock.

LABIATÆ.

Teucrium canadense Linnæus.
Scutellaria lateriflora Linnæus.
Scutellaria galericulata Linnæus.
Physostegia virginiana (Linnæus) Bentham.
Stachys palustris Linnæus.
Hedeoma pulegioides (Linnæus) Persoon.

Kœllia verticillata (Michaux) Kuntze.
Kœllia mutica (Michaux) Britton.
Lycopus uniflorus Michaux.
Lycopus americanus Muhlenberg.
Lycopus rubellus Moench.
Mentha spicata Linnæus.
Mentha piperita Linnæus.
Mentha cardiaca Gerarde.
Mentha canadensis Linnæus.

SOLANACEÆ.

Solanum dulcamara Linnæus.

SCROPHULARIACEÆ.

Mimulus ringens Linnæus.
Mimulus alatus Solander.
Dasystoma virginica (Linnæus) Britton.
Gerardia paupercula (A. Gray) Britton.
Castilleja coccinea (Linnæus) Sprengel.
Gustave Guttenberg, May 30, 1879. Carnegie Museum Herbarium.
Melampyrum lineare Lamarck.

LENTIBULARIACEÆ.

Utricularia cornuta Michaux.
Utricularia resupinata B. D. Greene.
Gustave Guttenberg, July and Aug., 1879. Carnegie Museum Herbarium.
Utricularia vulgaris Linnæus.
Utricularia clandestina Nuttall.[100]
Utricularia intermedia Hayne.
Utricularia minor Linnæus.
Gustave Guttenberg, Aug. 10, 1880. Carnegie Museum Herbarium.
Utricularia gibba Linnæus.

PHRYMACEÆ.

Phyrma leptostachya Linnæus.

PLANTAGINACEÆ.

Plantago major Linnæus.
Plantago lanceolata Linnæus.

[100] Porter, T. C. "Flora of Pennsylvania," p. 286.

RUBIACEÆ.

Cephalanthus occidentalis Linnæus.
Mitchella repens Linnæus.
Galium aparine Linnæus.
Galium pilosum Aiton.
Galium circæzans Michaux.
Galium triflorum Michaux.
Galium trifidum Linnæus.

CAPRIFOLIACEÆ.

Sambucus canadensis Linnæus.
Sambucus racemosa Linnæus.
Viburnum acerifolium Linnæus.
Viburnum dentatum Linnæus.
Viburnum lentago Linnæus.
Lonicera glaucescens Rydberg.
(Forms with purple flowers occur here.)
Diervilla diervilla (Linnæus) MacMillan.

CAMPANULACEÆ.

Campanula aparinoides Pursh.
Lobelia syphilitica Linnæus.
Lobelia kalmii Linnæus.

CICHORIACEÆ.

Taraxacam taraxacum (Linnæus) Karsten.
Lactuca canadensis Linnæus.
Hieracium canadense Michaux.
Hieracium paniculatum Linnæus.
Hieracium scabrum Michaux.
Hieracium gronovii Linnæus.
Nabalus albus (Linnæus) Hooker.

AMBROSIACEÆ.

Xanthium commune Britton.
Xanthium macounii Britton.
(The burs of these plants answer to the description of this species very nicely, but the leaves are apparently larger and more deeply lobed.)

COMPOSITÆ.

Eupatorium perfoliatum Linnæus.
Solidago cæsia Linnæus.

Solidago flexicaulis Linnæus.
Solidago serotina Aiton.
Solidago canadensis Linnæus.
Solidago nemoralis Aiton.
Euthamia graminifolia (Linnæus) Nuttall.
Aster novæ-angliæ Linnæus.
Aster ericoides Linnæus.
Aster polyphyllus Willdenow. (*Aster faxoni* Porter.)[101]
Erigeron philadelphicus Linnæus.
Erigeron ramosus (Walter) Britton, Sterns & Poggenburg.
Leptilon canadense (Linnæus) Britton.
Antennaria plantaginifolia (Linnæus) Richards.
Anaphalis margaritacea (Linnæus) Bentham & Hooker.
Gustave Guttenberg, Aug. 27, 1879. Carnegie Museum Herbarium
Gnaphalium polycephalum Michaux.
Gnaphalium decurrens Ives.
Gnaphalium uliginosum Linnæus.
Gnaphalium purpureum Linnæus.
Helianthus petiolaris Nuttall.[102]
Helianthus tracheliifolius Miller.
Helianthus strumosus Linnæus.
Bidens cernua Linnæus.
Bidens connata Muhlenberg.
Bidens beckii Torrey.
Achillea millefolium Linnæus.
Artemisia caudata Michaux.
Artemisia canadensis Michaux.
Artemisia biennis Willdenow.[103]
Tussilago farfara Linnæus.
J. A. Shafer, Sept. 9–11, 1900. Carnegie Museum Herbarium.
Erechtites hieracifolia (Linnæus) Rafinesque.
Senecio aureus Linnæus.
Carduus arvensis (Linnæus) Robson.
Total. — 420 species, 18 varieties, and 1 hybrid.

[101] Porter, T. C. "Flora of Pennsylvania," p. 325.
[102] Porter, T. C. "Flora of Pennsylvania," p. 332.
[103] Porter, T. C. *Ibid.*, p. 337.